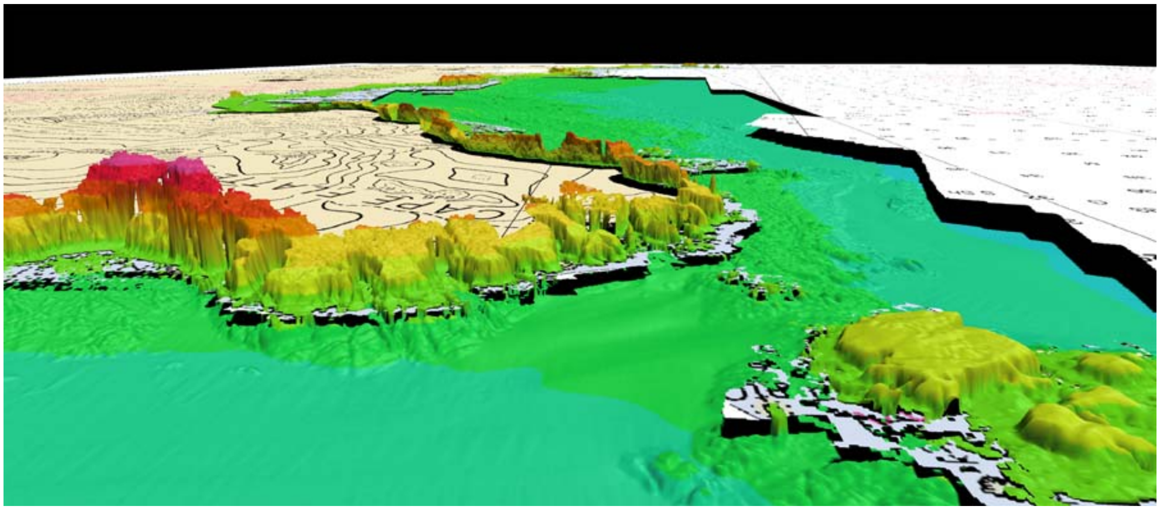
Marine Sanctuaries Conservation Series ONMS-06-05



Comments on Hydrographic and Topographic LIDAR Acquisition and Merging with Multibeam Sounding Data Acquired in the Olympic Coast National Marine Sanctuary

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service
Office of Ocean and Coastal Resource Management
Office of National Marine Sanctuaries

August 2006

About the Marine Sanctuaries Conservation Series

The National Oceanic and Atmospheric Administration's Office of National Marine Sanctuaries (ONMS) administers the National Marine Sanctuary Program. Its mission is to identify, designate, protect and manage the ecological, recreational, research, educational, historical, and aesthetic resources and qualities of nationally significant coastal and marine areas. The existing marine sanctuaries differ widely in their natural and historical resources and include nearshore and open ocean areas ranging in size from less than one to over 5,000 square miles. Protected habitats include rocky coasts, kelp forests, coral reefs, sea grass beds, estuarine habitats, hard and soft bottom habitats, segments of whale migration routes, and shipwrecks.

Because of considerable differences in settings, resources, and threats, each marine sanctuary has a tailored management plan. Conservation, education, research, monitoring and enforcement programs vary accordingly. The integration of these programs is fundamental to marine protected area management. The Marine Sanctuaries Conservation Series reflects and supports this integration by providing a forum for publication and discussion of the complex issues currently facing the National Marine Sanctuary Program. Topics of published reports vary substantially and may include descriptions of educational programs, discussions on resource management issues, and results of scientific research and monitoring projects. The series facilitates integration of natural sciences, socioeconomic and cultural sciences, education, and policy development to accomplish the diverse needs of NOAA's resource protection mandate.

Comments on Hydrographic and Topographic LIDAR Acquisition and Merging with Multibeam Sounding Data Acquired in the Olympic Coast National Marine Sanctuary

Steven S. Intelmann

Olympic Coast National Marine Sanctuary, NOAA

U.S. Department of Commerce
Carlos M. Gutierrez, Secretary

National Oceanic and Atmospheric Administration
VADM Conrad C. Lautenbacher, Jr. (USN-ret.)
Under Secretary of Commerce for Oceans and Atmosphere

National Ocean Service
John H. Dunnigan, Assistant Administrator

National Marine Sanctuary Program
Daniel J. Basta, Director

Silver Spring, Maryland
August 2006

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COVER

Perspective view of Cape Flattery and Tatoosh Island. Hydrographic and topographic LIDAR data merged with shallow water multibeam soundings and gridded at 4 meter resolution. The nautical chart was masked in Fledermaus with data obtained from both the 10 kHz and 1 Khz lasers.

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CONTACT

Steven S. Intelmann
Habitat Mapping Specialist
NOAA/National Marine Sanctuary Program
N/ORM 6X26
115 E. Railroad Avenue, Suite 301
Port Angeles, WA 98362
(360) 457-6622 X22
steve.intelmann@noaa.gov

ABSTRACT

In April 2005, a SHOALS 1000T LIDAR system was used as an efficient alternative for safely acquiring data to describe the existing conditions of nearshore bathymetry and the intertidal zone over an approximately 40.7 km^2 (11.8 nm^2) portion of hazardous coastline within the Olympic Coast National Marine Sanctuary (OCNMS). Data were logged from 1,593 km (860 nm) of track lines in just over 21 hours of flight time. Several islands and offshore rocks were also surveyed, and over 24,000 geo-referenced digital still photos were captured to assist with data cleaning and QA/QC. The 1 kHz bathymetry laser obtained a maximum water depth of 22.2 meters. Floating kelp beds, breaking surf lines and turbid water were all challenges to the survey. Although sea state was favorable for this time of the year, recent heavy rainfall and a persistent low-lying layer of fog reduced acquisition productivity. The existence of a completed VDatum model covering this same geographic region permitted the LIDAR data to be vertically transformed and merged with existing shallow water multibeam data and referenced to the mean lower low water (MLLW) tidal datum. Analysis of a multibeam bathymetry-LIDAR difference surface containing over 44,000 samples indicated surface deviations from –24.3 to 8.48 meters, with a mean difference of –0.967 meters, and standard deviation of 1.762 meters. Errors in data cleaning and false detections due to interference from surf, kelp, and turbidity likely account for the larger surface separations, while the remaining general surface difference trend could partially be attributed to a more dense data set, and shoal-biased cleaning, binning and gridding associated with the multibeam data for maintaining conservative least depths important for charting dangers to navigation.

KEY WORDS

Hydrographic LIDAR, Topographic LIDAR, SHOALS, multibeam, VDatum, Olympic Coast National Marine Sanctuary

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INTRODUCTION

Airborne LIDAR (light detection and ranging) technology developed throughout the 1990s is a new tool for use in bathymetric mapping. Today, airborne LIDAR bathymetry (ALB) has fully developed into a mature technology that is a cost effective means for quickly and efficiently obtaining bathymetry information, even in areas of hazardous conditions or in remote locations too difficult to survey through conventional acoustic methods (MacDonald 2005).

The initial commercialization of this new technology is, in part, traceable to a 1998 Memorandum of Agreement (MOA) between the U.S. Army Corps of Engineers (USACE) and the Naval Meteorology and Oceanography Command, which established the Joint Airborne LIDAR Bathymetry Technical Center of Expertise (JALBTCX) in an effort to create a mechanism for helping shape future developments and capabilities of ALB mapping (MOA1998). This original MOA was superceded in 2002 (MOA2002) by creation of a new MOA that added the National Oceanic and Atmospheric Administration’s (NOAA) National Ocean Service (NOS) and Office of Marine and Aviation Operations (OMAO) as partners. Expanding the breadth of partnership to include various facets of NOAA harnessed other existing capabilities, survey knowledge, tidal determination capabilities, and other unavailable resources.

In March 2005, under the NOS agreement code, a Support Agreement (MOA-2002-047 SA #001/1223) was written to facilitate the acquisition of LIDAR data for NOAA’s Olympic Coast National Marine Sanctuary (OCNMS) in Washington State. Under this Agreement, Fugro Pelagos, Inc. (FPI) was contracted by GRW Engineers to conduct a site survey for the USACE (and ultimately OCNMS) along a portion of coastline from Koitlah Point to Cape Alava within the OCNMS. OCNMS’ objectives for the survey effort were three-fold: 1) to obtain existing conditions of the nearshore bathymetry and intertidal zone along a select portion of shoreline that is not ascertainable through ship-based acoustic data acquisition techniques due to hazardous surf conditions, 2) to assess the performance of ALB technology along both exposed and unexposed stretches of coastline, and 3) to vertically transform the ALB data and assess agreement with existing shallow water multibeam bathymetry data collected in the same area.

SURVEY AREA

Approximately 40.7 km^2 (11.8 nm^2) of nearshore bathymetry and coastline between Koitlah Point and Cape Alava, in the general vicinity of Cape Flattery, and bounded by coordinates 48^o 08’38’’ N, 124^o 47’34’’W, and 48^o 24’46’’ N, 124^{o}38’11’’W (Figure 1) were proposed for surveying with a SHOALS 1000T LIDAR system. Survey flights occurred, or were attempted, between April 19 and April 24, 2005, with data being logged from 860 nm (1,593 km) of track lines in just over 21 hours of flight time. Bathymetry data was targeted between the shoreline and the approximate 15 meter bathymetry contour or laser extinction, which ever came first. Bathymetry data from the 1 kHz laser was acquired at 400 meters altitude, at 125 knots and with coverage plan designed to obtain 4 by 4 meter spot spacing using 25 percent line overlap. During project design, topographic survey lines were created to obtain heights 100 meters shoreward or to the mean higher high water (MHHW) line, which ever came first. Data from the 10 kHz topographic laser was acquired at 700 meters altitude, at 155 knots and with coverage designed to obtain 2 by 1.6 meter spot spacing. Several islands and offshore rocks were also surveyed, and over 24,000 geo-referenced digital still photos were simultaneously captured to assist with data cleaning and QA/QC.

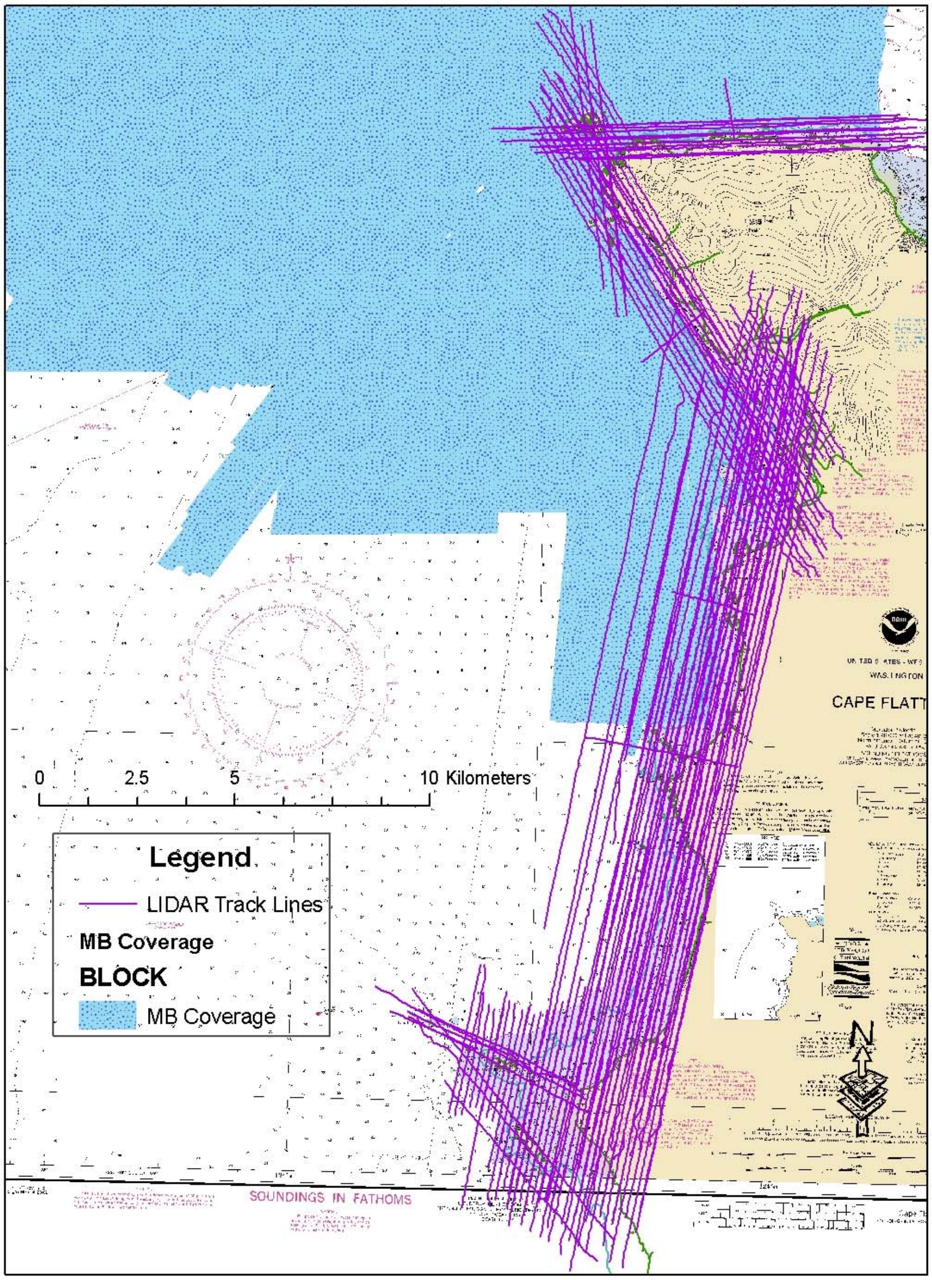


Figure 1. Cape Flattery LIDAR flight track lines, Koitlah Point to Cape Alava, shown with existing area of multibeam sounding data (blue polygon).

BASIC LIDAR FUNCTION

The basic principle of topographic LIDAR operation involves transmitting light in the form of a laser onto a mirror that is rotated at a high rate of speed. The rotating mirror projects the laser as a series of pulses onto the ground. Light is reflected back to the instrument, and with known vessel position, two-way time travel is used to ultimately compute the positional measurement of reflecting objects. ALB systems, however, are more sophisticated in theory because they must compensate for multiple reflective surfaces (i.e., the water surface and the seafloor). As such, ALB systems function as a multiple phase system where two different waves (infrared and green) are respectively used to detect the sea surface and sea floor. The newest generation of ALB systems, such as the one used for this particular survey, employs both types of LIDAR systems making them ideal for mapping shallow water intertidal zones as both height and sounding measurements can be delivered as a seamless data set. A seamless hydrographic and topographic LIDAR data set can then potentially be merged with acoustically derived single or multibeam bathymetry data, although a vertical datum transformation will likely be needed if the LIDAR data is acquired in an orthometric vertical datum and the multibeam data is referenced to some tidal datum such as MLLW (National Research Council 2004).

LIDAR DATA ACQUISITION AND PROCESSING

Details of the LIDAR acquisition and processing are in the attached Appendix, entitled "Hydrographic & Topographic LIDAR Acquisition, Northwest Coast, Washington, Neah Bay to Cape Alava, WA Survey Report" prepared by the FPI data center.

LIDAR SURVEY PRODUCT

Numerous shoals and hazardous surf conditions exist throughout the survey area, thereby precluding the use of ship-based acoustic multibeam for mapping the extreme nearshore zone in this area. LIDAR provided an efficient alternative for safely acquiring additional information to describe existing conditions of the nearshore bathymetry and intertidal areas throughout the Koitlah Point to Cape Alava region. As a general rule, the SHOALS 1000T (see Appendix for full description) is designed to obtain bottom depths of roughly 2.5 to 3 times the secchi depth. On April 15, 2004, 11 secchi measurements were taken throughout the proposed survey area in an effort to anticipate potential LIDAR performance (Figure 2). Secchi measurements ranged from 3.2 to 8.7 meters, indicating that bottom detection could potentially be achieved to anywhere between 8 and 26 meters, depending on water clarity at the time of the survey.

All topographic survey lines were fully completed and achieved with desired results; however, consistently poor weather conditions and a low-lying fog layer prevented any data acquisition from occurring on two of the six available survey days compromising bathymetry data acquisition efforts. Temporary cloud cover further restricted flying time on three additional days. As a result, significantly less data was acquired during the six-day time frame than had been hoped for. Very little bathymetry data was obtained in the southern region of the survey area due to weather constraints on survey time, poor water clarity resulting from recent significant rainfall and dense areas of kelp in the water column (Figure 3).

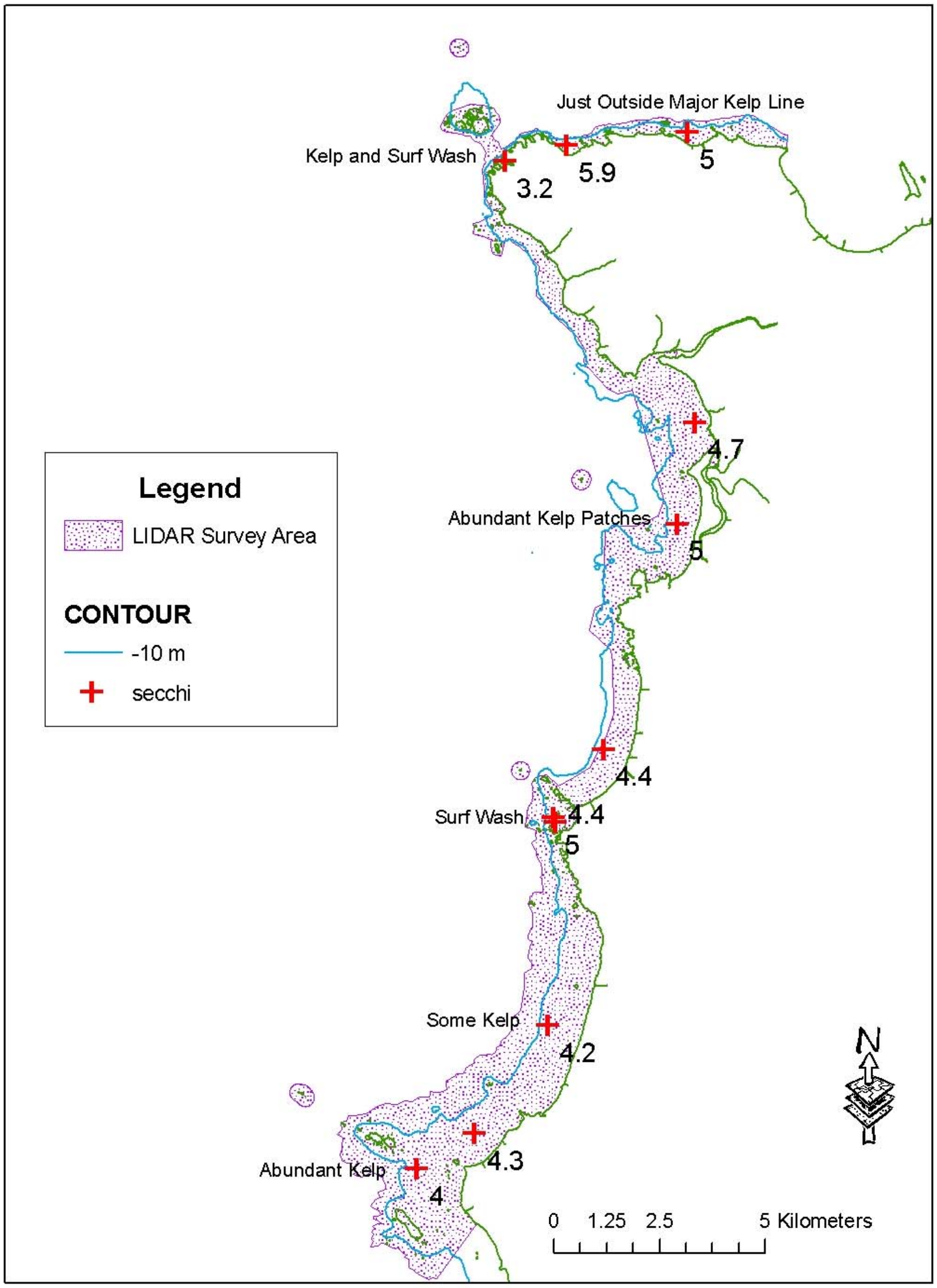


Figure 2. Locations of secchi measurements taken April 15, 2004. Secchi readings are in meters. Visual observations, if noteworthy, were also recorded at each site at the time of the measurement. The blue line represents the 10 m contour and purple polygon depicts the proposed survey boundary.

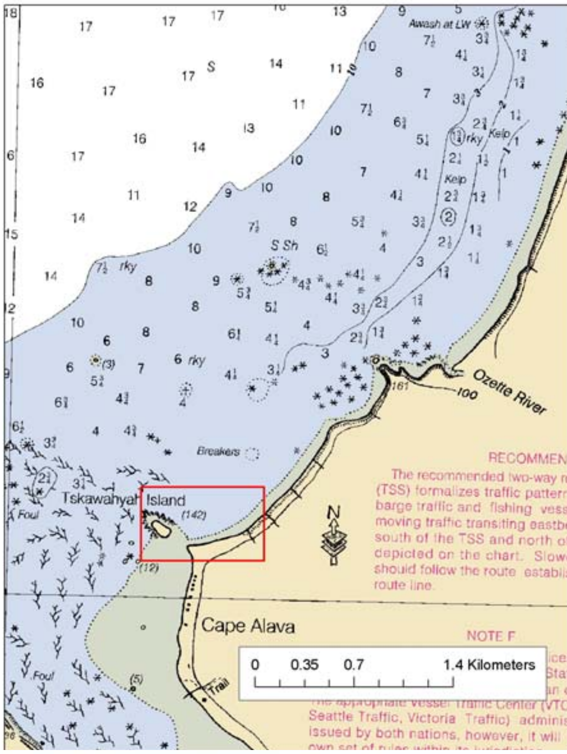
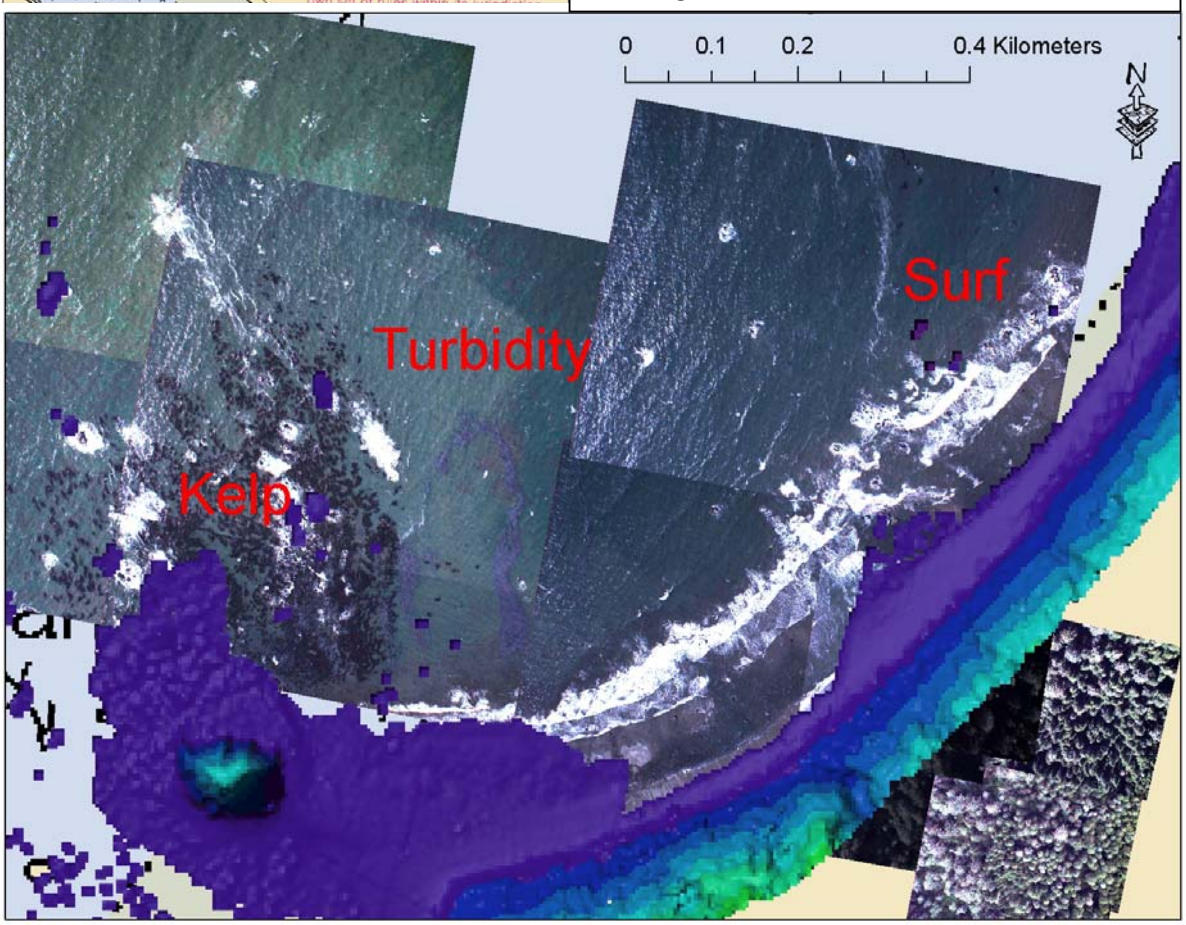


Figure 3. The graphic to the left represents the inset region of aerial photography provided below.

Surf breaks, kelp beds and turbid water all created challenges for acquiring bathymetry data in the southern portion of the survey area. All three challenges are clearly visible in the digital photo mosaic below. Images are overlaid with the accepted height data acquired from both the 1 kHz (bathymetry) and 10 kHz (topography) lasers. Example data are from the Tskawanyah Island area, and are gridded at 4 m resolution.



The effect of water clarity and inclement weather on survey productivity is immediately apparent when overlaying the actual LIDAR coverage achieved with the proposed survey area as shown in Figure 4.

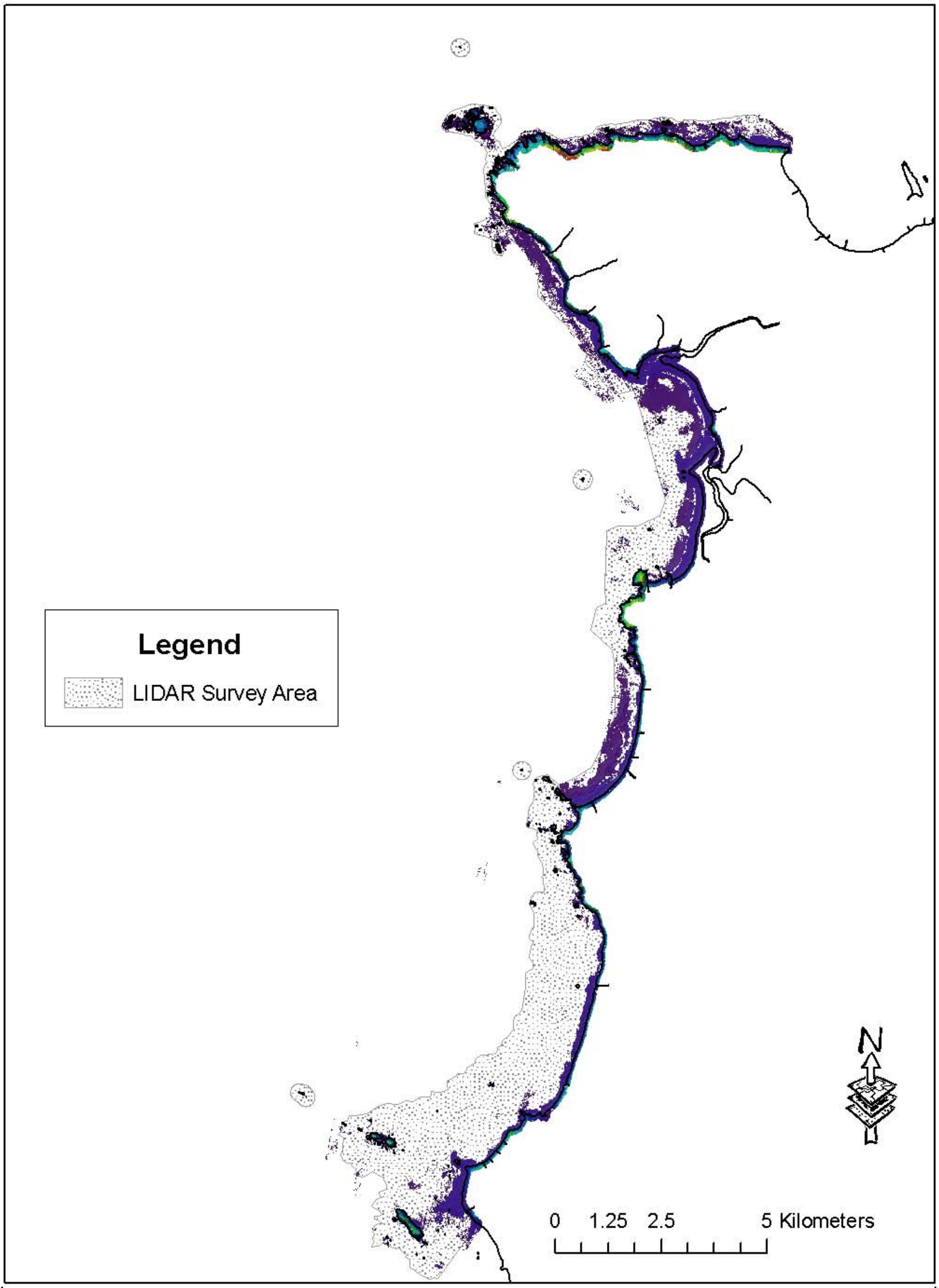


Figure 4. Combined hydrographic and topographic LIDAR coverage achieved over the six-day survey period. Heights and soundings are color ramped from red (highest surface elevation) to purple (deepest water depth). Grey polygon represents the proposed coverage area.

The maximum water depth obtained by the 1 kHz bathymetry laser was 22.2 meters, and it was located along the western shoreline of Tatoosh Island. This was near the maximum range that the secchi readings, although collected the previous year, suggested could be achieved.

DATA QUALITY ALONG EXPOSED AND UNEXPOSED COASTLINE

During the planning phase, there was concern over the suitability of LIDAR for being used as a bathymetry acquisition tool along this particular stretch of coastline. The degree of exposure to open ocean conditions and prevailing swell direction can at times produce considerable surf breaks in this area, through which the bathymetry laser would not penetrate. Having the survey designed around Cape Flattery, it provided an opportunity to assess the impact of open ocean exposure on the ability to successfully acquire ALB data in this area, as 6 km of relatively unexposed coastline exist immediately adjacent to roughly the same length of exposed coastline along the western edge of Cape Flattery (Figure 5).

Visual examination of LIDAR coverage did not suggest better LIDAR performance along the exposed stretch of coastline as compared to that along the unexposed (Figure 5). In fact when gridded at a 4 meter resolution, bathymetry data was obtained throughout 1.18 km^2 of the proposed 3.5 km^2 of exposed coastline (33.7 percent), in comparison to 1.03 km^2 of the proposed 3.05 km^2 (33.7 percent) of unexposed coastline along the Cape Flattery portion of the survey area. Furthermore, the deepest soundings obtained in the entire survey area (> 20m depth) were acquired along the exposed side of Tatoosh Island.

The bathymetry data along both these particular stretches of coastline were acquired on April 19, 22 and 23, 2006. Archived wave statistics obtained from the NOAA National Data Buoy Center (NDBC) for Station 46087, located approximately 11 km north of Tatoosh Island (48°29'38" N, 124°43'38" W), indicated that relatively calm seas occurred in this area throughout the entire survey effort. The buoy data shows the general wave trend for this particular time frame consisted of swell heights being less than 1.75 meters on a greater than 10 second swell period and with wind waves being less than 0.75 meters spaced on an roughly 4 second wave period (Figure 6). In general, both swell and wind direction came directly from the west during the survey flights (Table 1). The degree of swell and wave conditions at the time of survey were mild enough to not negatively impact the ALB data along the exposed coastline any more than that along the unexposed coastline. This indicates that other factors such as increased turbidity from recent rainfall and floating kelp played a more significant role than exposure in impairing laser penetration along this particular stretch of coastline.

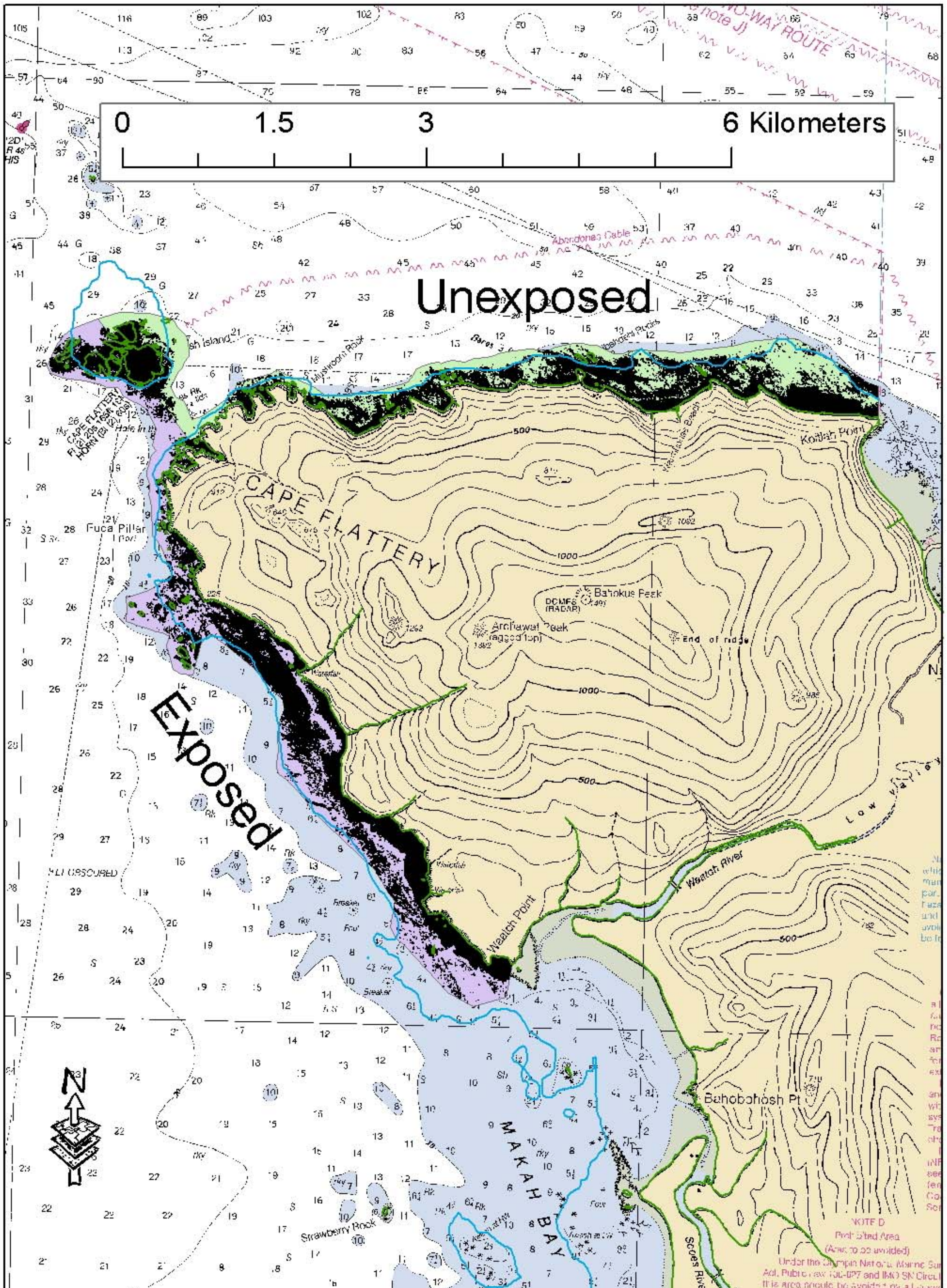


Figure 5. Adjacent stretches of exposed (purple) and unexposed (green) coastline within the proposed survey area. Achieved LIDAR bathymetry data are shown (black), with 10 meter bathymetry contour (blue).

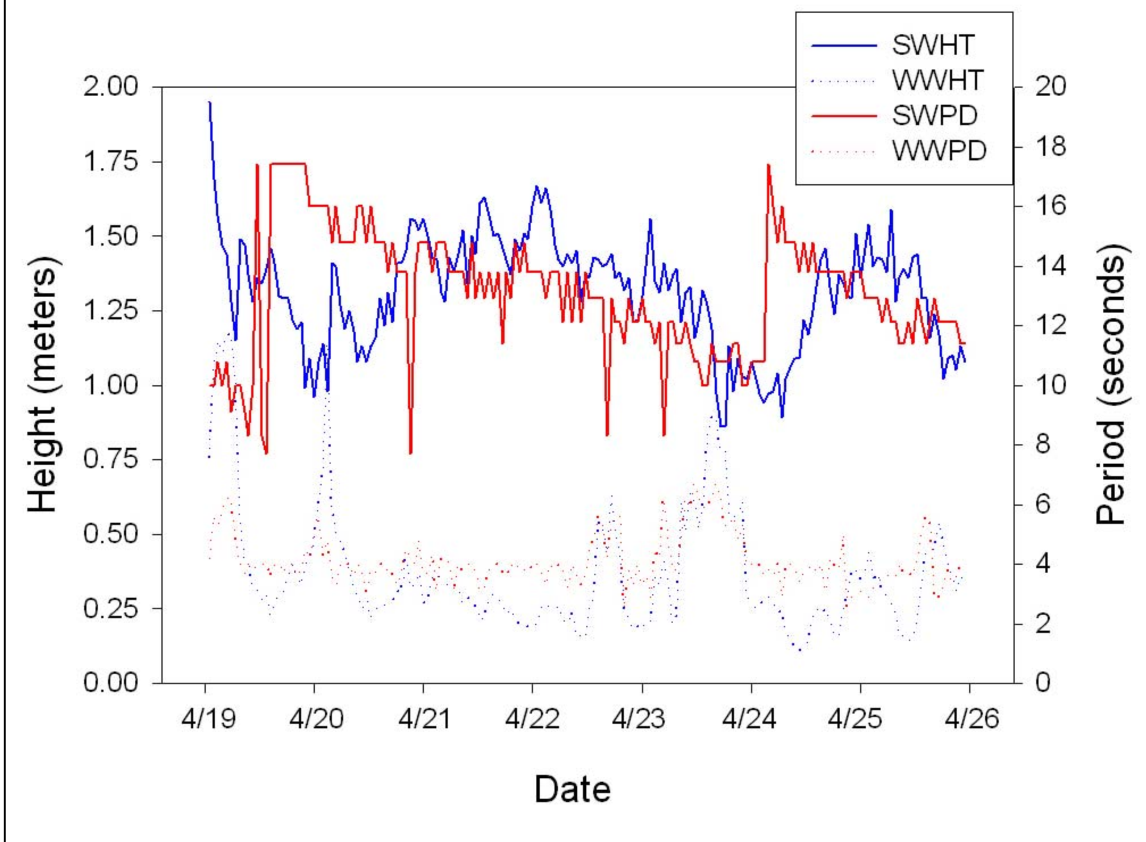


Figure 6. Archived wave summary statistics from NDBC station 46087, April 19-26, 2005 (UTC). SWHT = swell height, WWHT = wind wave height, SWPD = swell period, WWPD = wind wave period.

Table 1. Archived wave summary statistics from NDBC station 46087, April 19-26, 2005 (UTC). SWDIR = swell direction, WWDIR = wind wave direction. Values are azimuth degrees.

	SWDIR	WWDIR
Mean	272	265
Min	252	211
Max	294	357

LIDAR AND MULTIBEAM DATA MERGE

Through a partnership between OCNMS, NOAA's OCS and OMAO, high resolution bathymetry (HRB) was collected on various opportunistic occasions during the months of October from 2001 to 2004 aboard the NOAA ship *RAINIER* (Intelmann et al. 2006). Shallow water multibeam sounding data were cleaned according to NOAA standards (NOAA 2003), and were referenced to the MLLW tidal datum using the tide gauge at Neah Bay (Station 9443090) for datum control.

DGPS in the ellipsoidal datum of NAD83 supplied both the positional information and project control for the LIDAR survey. In order to easily merge the data set with existing multibeam sounding data, survey instructions required the data to be projected during post-processing and delivered in the UTM Zone 10 projection. The Geoid99 height model was used to convert the vertical datum from the ellipsoidal 3-D datum of NAD83 to the orthometric vertical datum NAVD88. In order to accurately merge the LIDAR data with existing multibeam sounding data, the data sets must be in the same vertical reference frame (Milbert 2002). Since the multibeam sounding data were referenced to an averaged tidally-derived vertical datum (MLLW) and the LIDAR data were referenced to an orthometric vertical datum (NAVD88) based on Mean Sea Level (MSL), a VDatum model (Spargo et. al 2006) was needed to vertically transform the LIDAR data to MLLW for compatibility and comparison with the multibeam sounding data. The VDatum model relates the NAVD88 to MLLW by using a grid or zone of tide model comparisons (Figure 7) with known leveled tide benchmark stations to better account for the spatial variability of tidal dynamics over a given area (Milbert 2002; Spargo et. al 2006). The VDatum model that was used is available for download at *http://chartmaker.ncd.noaa.gov/csdl/vdatum_projectsWA.htm.*

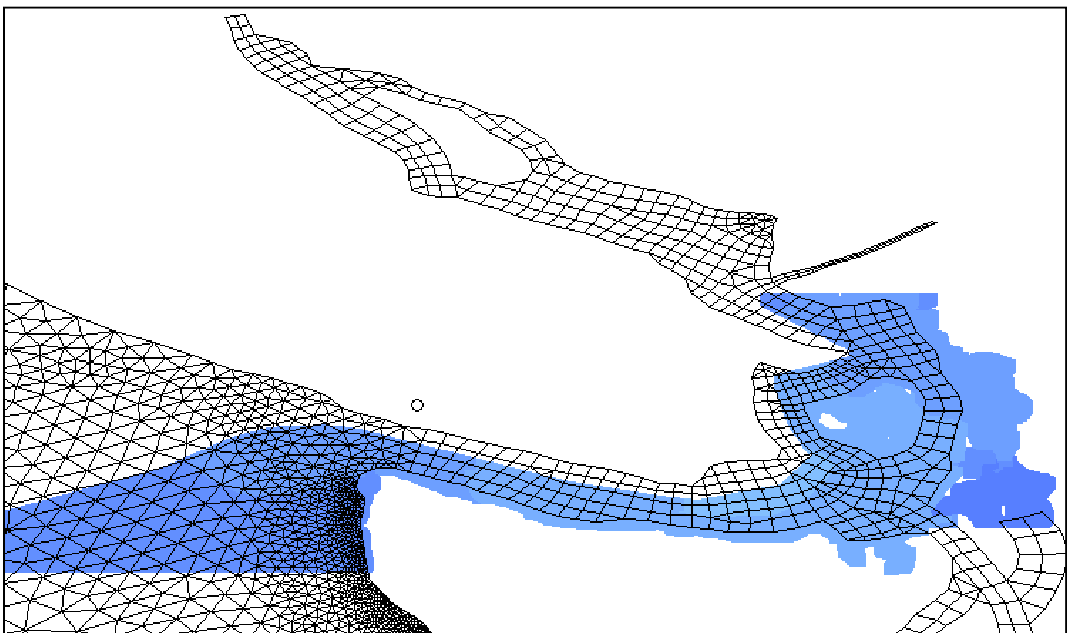


Figure 7. VDatum tide modeling grid for the San Juan Islands, Strait of Juan de Fuca and Puget Sound (Spargo et al. 2006).

Both the multibeam sounding and LIDAR xyz data were imported into Fledermaus using AVGGrid with 4 meter grid spacing (Figure 8), and then exported as separate ESRI floating-point ASCII grids for surface comparison.

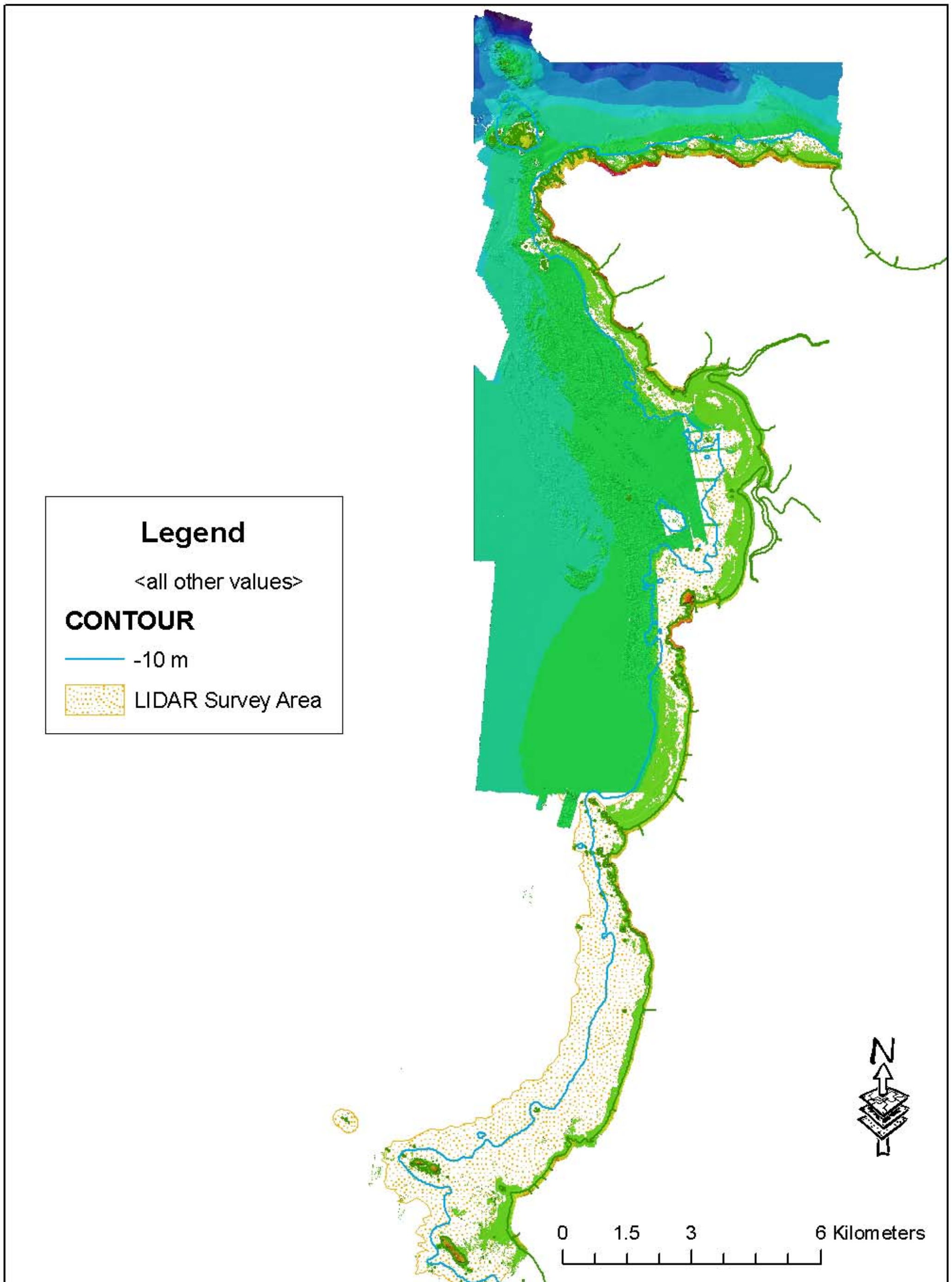


Figure 8. Multibeam sounding data combined with bathymetry and topographic LIDAR data sets. Data are gridded at 4 meter resolution. Visible areas of the brown-dotted polygon are "holidays" in LIDAR acquisition due to poor water clarity. 10 m isobath is shown as the blue line.

The two ASCII grids were converted to polygon features and intersected in ARCInfo to create a mask polygon. ARCInfo grid was then used to mask each of the ASCII grids with the intersect polygon, thus creating two new grids that were only populated with cells for which each data set had in common. The two new grids, which now contained only data common to both surfaces, were exported again as separate ASCII grid files and then imported back into Fledermaus using AVGGrid with 4 meter spacing. A difference DTM was created in Fledermaus by subtracting the LIDAR surface from the multibeam sounding surface to produce a new difference surface. The difference surface contained over 44,000 samples for which each grid had in common, with depth differences ranging from –24.3 to 8.48 meters, a mean difference of –0.967 and standard deviation of 1.762 meters (Figure 9). Depth differences between the LIDAR and multibeam surfaces were further compared to the acoustic multibeam data alone, assuming the acoustic soundings represent a more accurate reference benchmark surface (Riley 1995). As with Riley (1995), no attempt was made to assess individual error contribution to each data source.

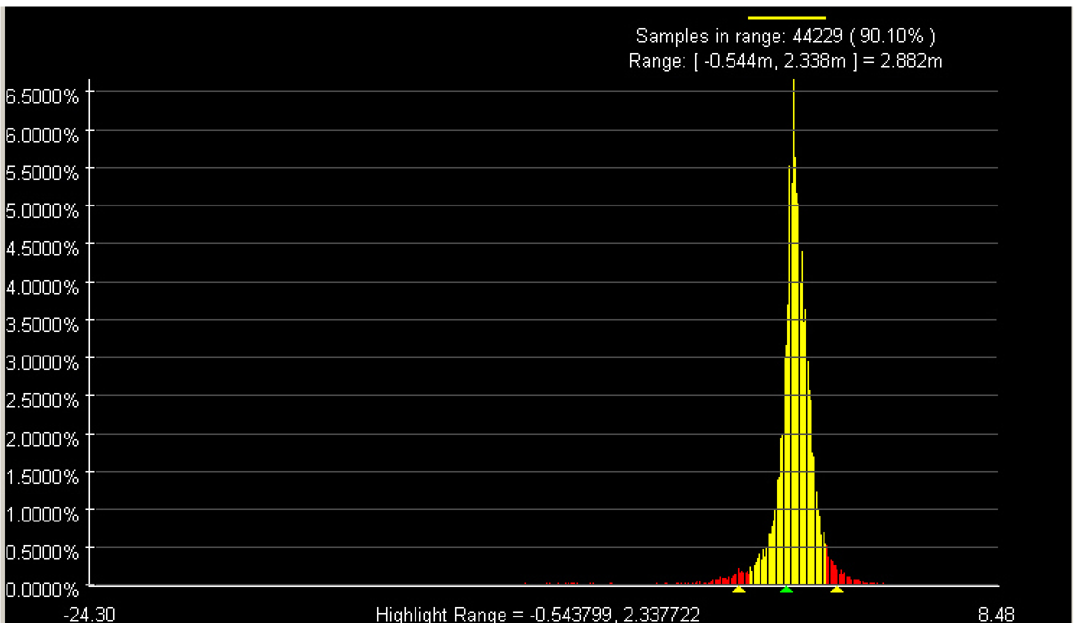


Figure 9. Depth difference histogram. The 2 * Std. Deviation (90 percentile) range is highlighted in yellow. Depth difference in meters (Multibeam Surface – LIDAR Surface) is represented by the X-axis, and the Y-axis is the percentage of samples contained in each difference bucket category.

The extreme deviations observed in the least squares fit between the multibeam and LIDAR surfaces are attributed to false bottom detections in the LIDAR depths due to water column interference (Figure 10). When examining only the 90th percentile sample range (-0.54–2.33 m depth difference), the multibeam sounding data are for the majority about 1 to 1.5 meters more shoal than the LIDAR data. This is not surprising since multibeam systems produce more dense data thus leading to delineation of more shoal features. This shoal bias of the multibeam data can be more easily visualized through Figure 11 where the enhanced surface difference is readily distinguished by examining

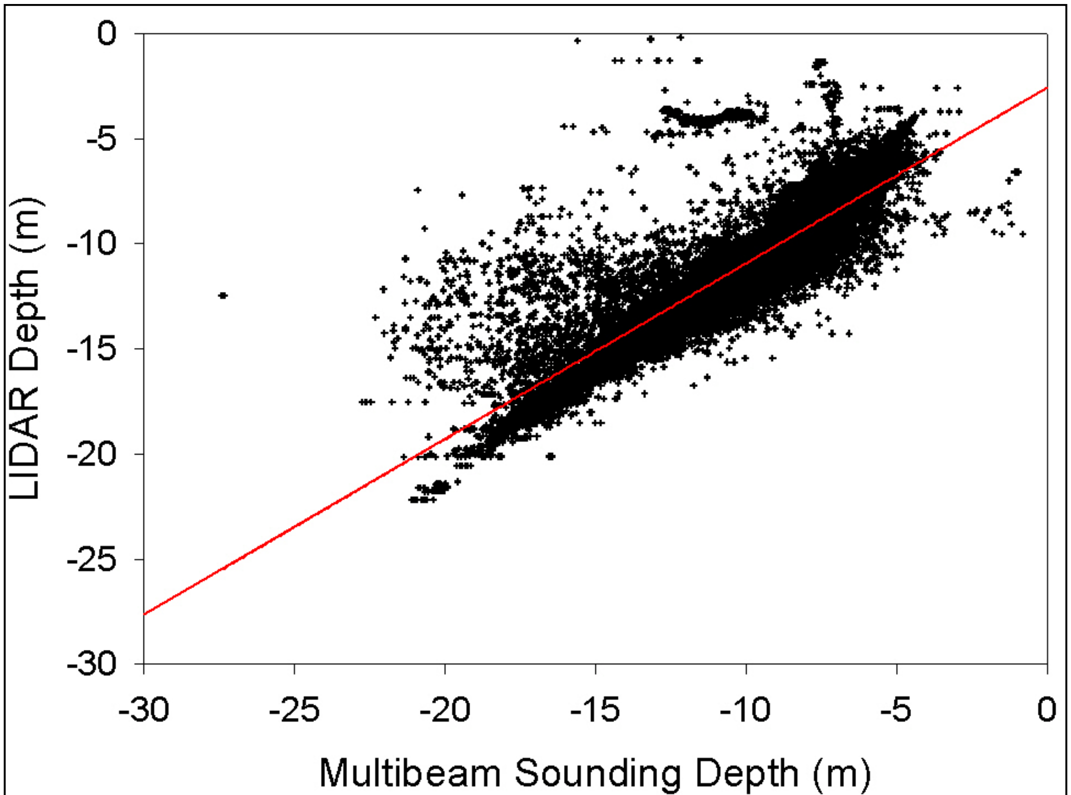


Figure 10. Linear least squares data model between multibeam soundings and LIDAR depths (m). LIDAR = -2.576+0.835*Multibeam sounding depth, R-Squared = 0.682.

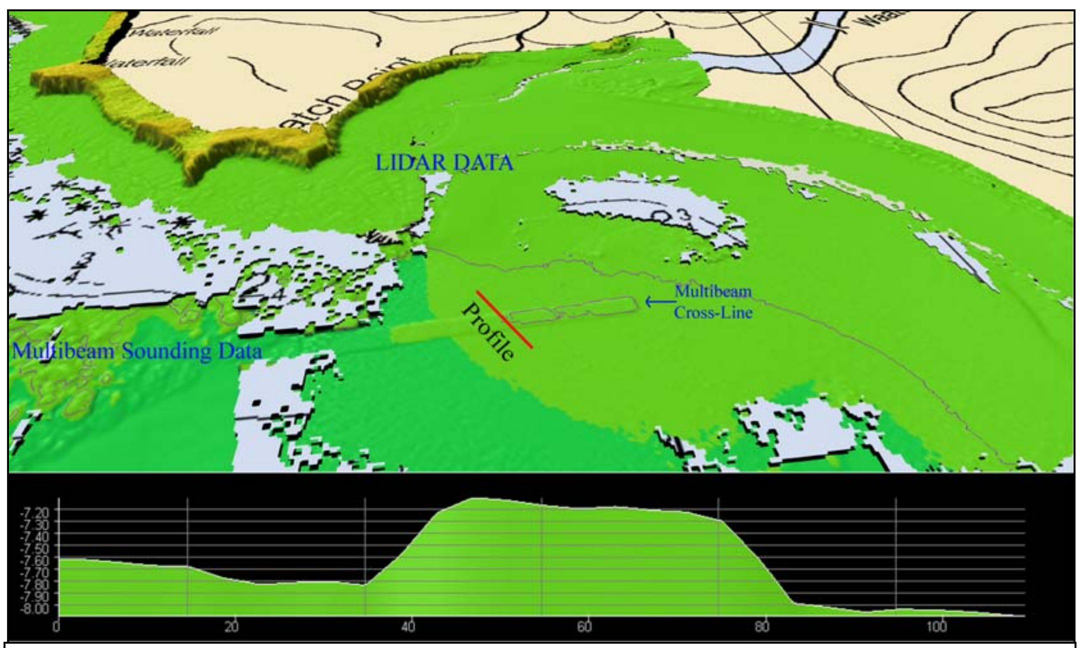


Figure 11. Multibeam and LIDAR xyz data merged into seamless DTM covering Makah Bay. Note the multibeam cross line is about 0.5 m more shoal than the LIDAR surface. Red line represents the location and extent of the bathymetry profile shown on the bottom. Purple contour is the 7 m bathymetry curve.

the cross line of multibeam data. The largest of the depth differences, those values in the extreme tails of the histogram (red portion of the sample range in Figure 8), are traceable to two distinct areas and appear to be artifacts of errors in LIDAR data cleaning due to interference from false bottom detection (Figure 12). The remaining general surface difference trend could be attributed to the fact that the multibeam data are cleaned and gridded with a shoal biased constraint to be more conservative with respect to dangers to navigation.

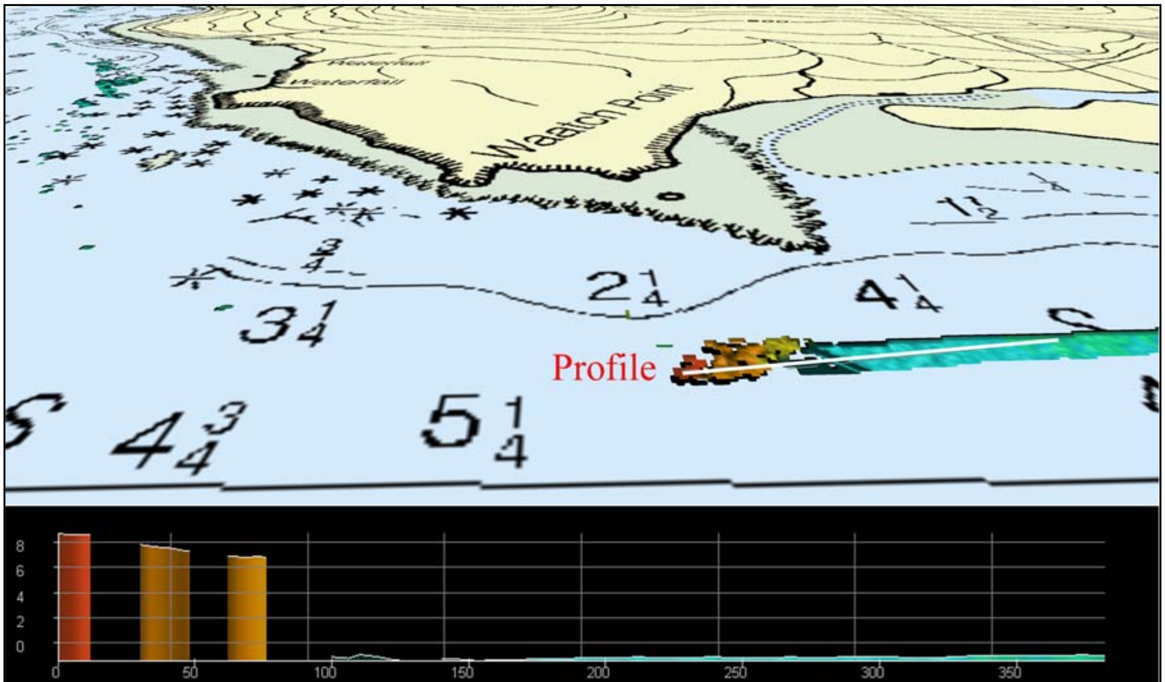


Figure 12. An area of significant surface difference (red and orange pixels) attributed to improper cleaning of the LIDAR data resultant from surface interference. The white line shows extent and location of profile, which indicates an 8 meter surface difference at the western end of the line and sub-meter surface difference (green and blue pixels) throughout the remainder.

DISCUSSION AND CONCLUSIONS

As with most coastal ALB surveys, floating kelp beds, breaking surf lines and turbid water were challenges to this survey. The window of opportunity for capturing favorable environmental conditions to successfully acquire ALB in coastal areas, such as OCNMS, is narrow. Avoiding the detrimental effects of turbid water created from excessively aerated breaking surf and increased surface runoff from heavy spring rains require data acquisition to be targeted for late spring to early summer. However, kelp growth and increased biological productivity can further impede the rate of acquisition success in this region beginning as early as May. Because of all these factors for attempting to acquire the LIDAR data for this particular survey, late April was selected.

The less than 2 meter swell and minimal wind-induced wave action that were experienced did not appear to negatively impact data quality over the course of the survey, indicating that ALB can successfully be achieved in this area at these particular sea states. Although sea state was favorable for this time of the year, recent heavy rainfall and a persistent low-lying fog layer severely reduced the productivity of this survey. Additional project funds would have been helpful to keep the mobilized flight crew on site while survey conditions continued to improve in order to maximize acquisition success.

The existence of a completed VDatum model covering this geographic region permitted the LIDAR data to be seamlessly merged with shallow water multibeam data using the same control datum. Of note, since OCNMS uses UTM coordinates to position all multibeam sounding data, it was required that the contractor deliver the NAVD88 referenced z-values in that same coordinate system. Unfortunately, it was later determined that VDatum Version 1.06 only accepts geographic coordinates, thus the positional information delivered by FPI in UTM had to be unprojected back to latitude and longitude (decimal degrees) prior to transforming the vertical units. This was a very time consuming step, which in retrospect, could have been avoided by simply not requiring the contractor to project the data prior to transformation. The VDatum tool would benefit from a future enhancement to address this limitation.

Despite relatively poor survey productivity resulting from poor flying conditions, a significant portion of nearshore bathymetry was acquired along the Cape Flattery coastline. The entire intertidal zone from Koitlah Point to Cape Alava, including numerous offshore rocks and islands, was also better defined by the high-resolution topographic LIDAR elevation data. The bathymetry data that were successfully acquired could potentially provide useful information for delineating rock features in many areas that were too hazardous to access through ship-based acoustic survey methods. Due to a lack of project funds and a desire to cover as much area as possible, this survey was designed to acquire 4 by 4 m spot spacing bathymetry data with just 100 percent coverage. Even though NOAA’s OCS often requires 200 percent coverage for bathymetric LIDAR acquisition at a 4 by 4 spot spacing, it is possible that the data could still be used to update the Cape Flattery nautical chart 18485. Many of the least depths recorded on that chart are rather dated with some soundings potentially being obtained as early as 1834 (NOAA 2002). But it is important to stress that this survey was not designed or performed for nautical charting purposes and several critical levels of quality control were not implemented to evaluate and process the data for such purposes. Therefore the data will be submitted to NOAA’s Hydrographic Survey Division for outside-source evaluation and archival at the very least. Various other elements within the NOS Hydrographic Surveys Specifications and Deliverables (2003) will also need to be assessed prior to electing the data for possible inclusion on the nautical charts.

LIDAR technology continues to evolve at a rapid pace. In the short time since this data was acquired, significant improvements have been made to the acquisition algorithms in order to increase extraction of more useful information for aiding environmental assessment (Francis and Tuell 2005). For example, in addition to acquiring depth and digital still frames, as with the SHOALS 1000T system used here, the new Compact Hydrographic Airborne Rapid Total Survey (CHARTS) system now has the ability to measure hyperspectral data, and it can produce seafloor reflectance images, as well (Tuell et al. in press). This new system could be an extremely useful tool for the National Marine Sanctuary Program (NMSP) by providing the ability to rapidly gain knowledge of both coastal and nearshore topography, combined with water column characteristics and seafloor reflectance – all of which are important components for understanding changes to the nearshore coastal and benthic environment.

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APPENDIX

Hydrographic & Topographic LIDAR Acquisition, Northwest Coast, Washington, Neah Bay to Cape Alava, WA Survey Report.

Hydrographic & Topographic LIDAR Acquisition

Northwest Coast, Washington

Neah Bay to Cape Alava, WA

Survey Report

Fugro Document No: FP-6088-012-RPT-01-00
Contract Number: DACW01-02-D-0008/039
EN Project Number C-05-017

Applicable to:	**Fugro Pelagos, Inc.**
Controlled by:	**Data Center** **Fugro Pelagos, Inc.** **3738 Ruffin Road** **San Diego, CA 92123**
Telephone:	**(858) 292-8922**
Facsimile:	**(858) 292-5308**

REPORT CERTIFICATION FOR

Hydrographic and Topographic LIDAR Acquisition

Northwest Coast, Washington

Neah Bay to Cape Alava, WA

FP-6088-012-RPT-01-01

This issue of the report has been approved by:

1.	Vice President Coastal Mapping and LIDAR Services	David Millar
2.	Project Manager – LIDAR	Carol Lockhart

This report has been distributed to:

1.	Eddie Culpepper, U.S. Army Corps of Engineers, Spatial Data Branch (OP-J), 109St Joseph St, Mobile, AL 36602	1 Copy
2.	Steven S. Intelmann Olympic Coast National Marine Sanctuary National Oceanic and Atmospheric Administration 115 E. Railroad Avenue, Suite 301 Port Angeles, WA 98362 360-457-6622, Ext. 22	1 Copy

The following versions of this report have been issued:

0	05/24/2005	Neah Bay to Cape Alava, WA	DJ	CAL	
REV	DATE	DESCRIPTION	APPROVED		

APPENDIX A : DAILY LOG

APPENDIX B : GROUND CONTROL EQUIPMENT

APPENDIX C : NGS DATASHEET (TS0340)

APPENDIX D : GPS BASE STATION FIELD LOGS

APPENDIX E : STATION DECSRIPTIONS (NEA1)

APPENDIX F : AIRCRAFT SPECIFICATIONS

APPENDIX G : SHOALS-1000T EQUIPMENT SPECIFICATIONS

APPENDIX H : OPUS SOLUTIONS

APPENDIX I : SHOALS CALIBRATION VALUES USED

APPENDIX J : KGPS PROCESSING RESULTS

APPENDIX K : PERSONNEL

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1 INTRODUCTION

Fugro Pelagos, Inc., (FPI), was contracted by GRW Engineers to conduct a site survey for the Unites States Army Corps of Engineers (USACE) along the northwestern coastline of Washington State (Figure 1-1), from Neah Bay to Cape Alava, as shown in Figure 1-1.

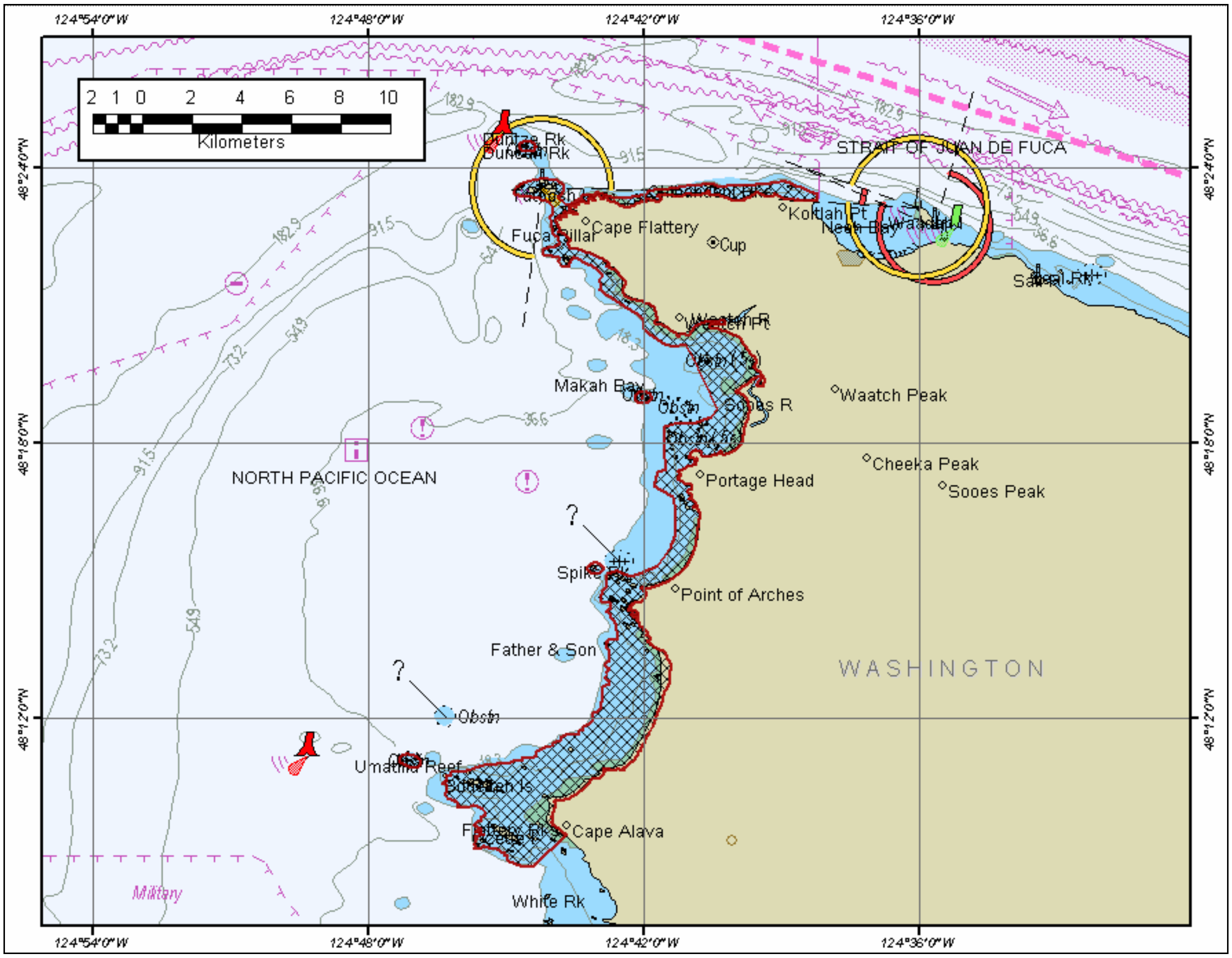


Figure 1-1 Survey Location

The objective of the survey was to obtain the existing conditions of the near shore bathymetry and beach.

The survey took place on April 18th to April 24th 2005 (J.D. 108 to 114), during which the following information were collected:

- Bathymetric LIDAR data from the SHOALS-1000T
- Topographic LIDAR data from the SHOALS-1000T
- Digital Aerial Photography from the SHOALS-1000T
- GPS Ground Control

All times quoted in this report are UTC, unless otherwise stated.

1.1 AREA SURVEYED

The total area surveyed was approximately 15.7 nm^2 (40.7 km^2) in size. Water depth ranged from the shoreline to approximately 15m, or laser extinction, depending on water clarity.

The bathymetric laser was operated to achieve 4m x 4m spot spacing flying at 400m altitude and approximately 124 knots. The survey lines were planned with 25% overlap.

The topographic laser was operated to achieve 2m x 1.6m spot spacing flying at 700m altitude and approximately 155 knots. The survey lines were planned to achieve shoreline data in the survey area inshore to 100m or MHHW, whichever came first. Additional lines were run to collect topographic data over islands and offshore surface features.

2 DATA ACQUISITION

Operations for this survey were based out of the Best Western Olympic Lodge, Port Angeles, WA, where a temporary office base was established.

Ground control personnel were stationed at the Tyee Motel in Neah Bay, WA for the duration of the project. The base airport for operations was Fairchild International Airport in Port Angeles, WA. Once the aircraft was ready to depart, the ground control personnel were informed via cell phone, and the ground equipment switched on. The aircraft was then readied for take off and the plane departed with the airborne operators on board to start survey.

A detailed daily log is given in APPENDIX A

2.1 PROJECT DATUM

Position information supplied by the DGPS was in the NAD83 datum (Table 2-1) and all online surveys were conducted using this datum. Project control was also acquired in NAD83 and all data were post-processed in this datum. Data sets were later projected during processing to UTM Zone 10 (NAD83) in meters, for final deliverables (Table 2-2).

The vertical datum for the project was NAVD88 with units of meters. Geoid99 was used to convert between NAD83 and NAVD88.

Table 2-1 Project Datum

Datum	NAD83
Spheroid	GRS80
Semi-major Axis	6378137.000
Semi-minor Axis	6356752.3141
Inverse Flattening (1/f)	298.257222101

Table 2-2 Project Projection

Projection	UTM
Zone	10 N
Central Meridian (C.M.)	123° W
False Easting	500000 m
False Northing	0 m

2.2 GROUND CONTROL

In order that a post-processed Kinematic GPS (KGPS) solution could be used for final positioning and refinement of the inertial solution, it was necessary to acquire dual frequency GPS data at a known location on the ground.

In addition, it was necessary that the control point have known elevations in both the processed ellipsoidal datum and the final charting datum, in this case NAD83 and NAVD88.

Detailed specifications for all ground control equipment can be found in APPENDIX B.

2.2.1 HORIZONTAL CONTROL

The primary ground control point for this survey was the National Geodetic Survey (NGS) control monument PID# TS0340 (Table 2-3), located in the town of Neah Bay, WA. A secondary control point, NEA1, was also established close to TS0340. Both points are located at the west end of an indian burial site, adjacent to Bayview Dr (Figure 2-1). The NGS data sheet for TS0340 is provided in APPENDIX C.

Table 2-3 Primary Ground Control (TS0340)

Designation	944 3090 A TIDAL
PID	TS0340
Horizontal Order	B
Latitude (N)	48° 22' 00.7451"1
Longitude (W)	124° 37' 15.66974"
VM #	1109
NAVD88 Height (m)	5.675 m

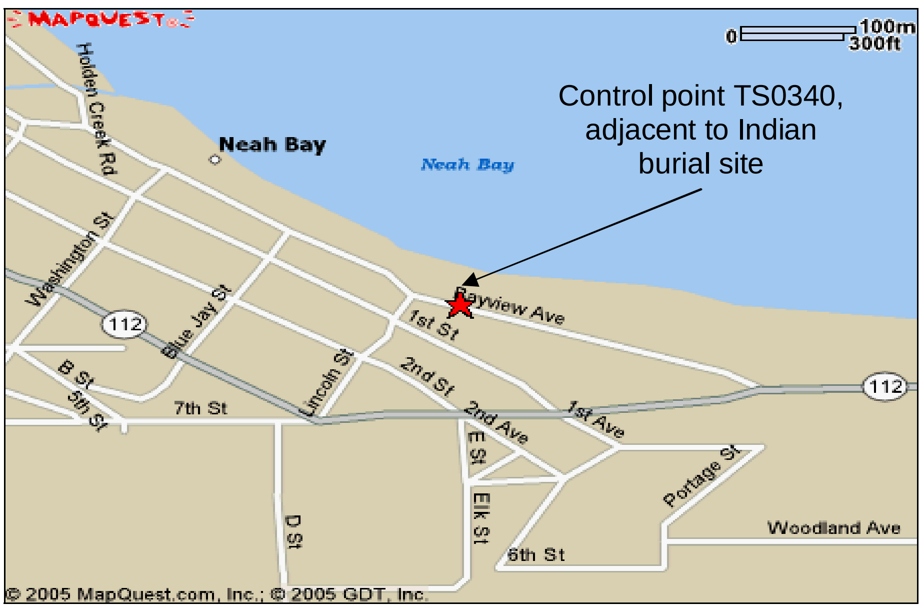


Figure 2-1 Location of Ground Control at Neah Bay

The secondary ground control point, NEA1, was established for this survey near the NGS control point detailed above. A PK nail was driven into an existing 4"x4" post that was previously driven into the ground to secure a water spigot (Figure 2-2).

Figure 2-2 Secondary Control Point NEA1 and Proximity to TS0340

Dual frequency GPS data were acquired over TS0340 and NEA1 at 1-second intervals using Thales Z-Max GPS systems. Logging commenced prior to aircraft take-off at Fairchild International Airport and ended after the aircraft had left the area.

GPS field logs for TS0340 and NEA1 can be found in APPENDIX D, while station descriptions can be found in APPENDIX E.

2.2.2 VERTICAL CONTROL

National Geodetic Survey (NGS) benchmark TS0340, was also used for vertical control. Data were converted from the NAD83 ellipsoid to NAVD88 heights using Geoid99 during processing.

2.2.3 SECCHI DISK MEASUREMENTS

No Secchi disks measurements were recorded for this project. As a rule of thumb, the SHOALS 1000T is capable of sensing the bottom to depths equal to 2.5 to 3 times the Secchi depth.

2.3 AIRBORNE SURVEY

The Beechcraft King Air 90 (call sign N80Y) equipped with a SHOALS-1000T Bathymetric and Topographic LIDAR System was used for the project (Figure 2-3). Technical specifications for the plane are located in APPENDIX F. Detailed equipment specifications for the SHOALS-1000T are available in APPENDIX G.

Figure 2-3 Beechcraft King Air (N80Y)

2.3.1 AIRCRAFT MOBILIZATION

The aircraft was mobilized at Buttonville Airport, Ontario, Canada with the assistance of Optech staff. The airborne component of the SHOALS-1000T consists of three separate modules. The lasers and camera are housed in a single package that was bolted to a flange above the aircraft camera door. An equipment rack, containing the system cooler and power supplies, was installed aft of the laser. The operators console was attached to the seat rails foreword of the power supply. The console was installed so the operator was facing forward. All hardware was located on the starboard side of the aircraft. Equipment installation required about 2 hours.

2.3.1.1 OFFSET MEASUREMENTS

The only offset measurement required during system mobilization is from the POS AV Inertial Measurement Unit (IMU) to the POS AV GPS antenna. The IMU is completely enclosed within the laser housing. The offsets from the IMU to a common measuring point (CMP) on the outside of the housing are known.

Offsets were measured using a total station. An arbitrary base line was established along the port side of the aircraft. Ranges and bearings were measured from the total station to the CMP on the top of the laser housing. Additional measurements where made to the sides and top of the housing to determine its orientation. A final measurement was made to the center of the POS AV GPS antenna. The IMU to POS AV GPS offsets are calculated using the known IMU to CMP offsets. A summary of the offset measurements can be found in Table 2-4, below.

Table 2-4 Aircraft Offsets

OFFSET	X	Y	Z
IMU to CMP	0.073	-0.230	-0.415
CMP to POS AV GPS Antenna	1.345	-0.171	-0.939
IMU to POS AV GPS Antenna	1.418	-0.401	-1.354

The offsets from the IMU to the POS AV GPS antenna are entered in to the POS AV console prior to survey.

2.3.2 POSITIONING

Position was determined in real time using a DGPS (Differential Global Positioning System). However, final positions were determined using a post-processed Kinematic GPS solution (Section 3.2.2).

The primary position GPS antenna was a NovAtel 512 airborne L1/L2, which was connected to a NovAtel Millennium GPS card residing in the POS AV (Section 2.3.3)

An AeroAntenna AT-3065-9 antenna was used to acquire differential corrections. Two differential receivers were available: the OmniSTAR 3100LM and a CSI MBX-3S Coast Guard beacon receiver. The OmniSTAR was the primary source of differential corrections for this project.

Dual frequency GPS data was also acquired with the NovAtel Millennium card in the POS AV. These data were used in post-processing, along with the dual frequency ground control data to provide a KGPS solution.

2.3.3 SENSOR ORIENTATION

The Applanix POS AV 410 measured orientation (roll, pitch and heading). The system consists of a POS AV computer with a NovAtel Millennium GPS card, an Inertial Measuring Unit (IMU), and one NovAtel 512 airborne L1/L2 GPS antenna.

The IMU is permanently mounted within the SHOALS-1000T sensor. It uses a series of linear accelerometers and angular rate sensors that work in tandem to determine orientation.

The orientation information is used in post-processing to determine position of the laser spots. However, analog data from the POS AV is also used during acquisition to maintain a consistent laser scan pattern.

2.3.4 LIDAR SYSTEM

The SHOALS-1000T was used to acquire both bathymetric and topographic LIDAR data during the project.

The 1 kHz bathymetric laser (or hydro laser) was used to collect data over the entire survey area. All hydrographic lines were run at a 400m altitude and 126 knots with a 4x4m spot spacing. Background theory on bathymetric LIDAR can be found in the paper, "*Meeting the Accuracy Challenge in Airborne LIDAR Bathymetry*" (Guenther, et al.[1]). However, in general, the laser outputs a green and infrared beam. The infrared beam is used to detect the water surface and does not penetrate this. The green beam penetrates through the water and is used to detect the seafloor. The green beam also generates red energy when excited at the air/water interface. This is known as Raman backscatter and can be used to detect the sea surface as well. Distances to the sea surface and seafloor are calculated from the times of the laser pulses, using the speed of light in air and water.

The 10 kHz topographic laser was used to collect elevations over the islands, shoal areas offshore and along the shoreline of the survey area inland to 100m or MHHW, which ever came first. The topographic lines were run at a 700m altitude and 155 knots with a 2x1.6m spot spacing.

Data received by the airborne system was continually monitored for data quality during acquisition operations. Display windows showed coverage and information about the system status. In addition, center waveforms at 5Hz were shown. All of this information allowed the airborne operator to assess the quality of data being collected.

In addition to LIDAR data, a DuncanTech DT4000 digital camera was also used to acquire one 24-bit color photo per second. The camera, mounted in a bracket at the rear of the sensor, captures imagery of the area being over flown, and can be used during post-processing.

2.3.4.1 LIDAR CALIBRATION

A LIDAR in-flight calibration was performed at Toronto, Ontario, Canada in March of 2005. This "raster pattern" calibration is used in the determination of the small offsets of the scanner mirror frame relative to the optical axes of the system. To calculate the angular offsets an average of the water surface is derived by the system. The raster pattern calibration required flying reciprocal straight lines over a relatively calm water surface for at least 5 minutes. In addition, ground truth data were acquired over Oshawa runway, and these were used to determine system biases.

2.4 CHALLENGES ENCOUNTERED

The main challenges encountered during the survey were poor weather conditions and turbid water.

Many flights attempted during the project were unsuccessful due to poor weather, or a low lying marine layer across the survey area. However, all topographic lines were completed and good topographic data were acquired over the majority of the survey area.

[1] *"Meeting the Accuracy Challenge in Airborne LIDAR Bathymetry", Gary C. Guenther, A. Grant Cunningham, Paul E. LaRocque, David J. Reid*

The hydrographic data collection was not as successful, with many data dropouts occurring due to poor water clarity conditions. Wave action, recent rainfall, run-off, and kelp were all believed to be factors contributing to the turbidity.

3 DATA PROCESSING

Data were provisionally processed at the temporary office base in Port Angeles, WA to determine data coverage. The remaining data were processed in Fugro Pelagos' San Diego office. An overall processing flow is given in Figure 3-1, below.

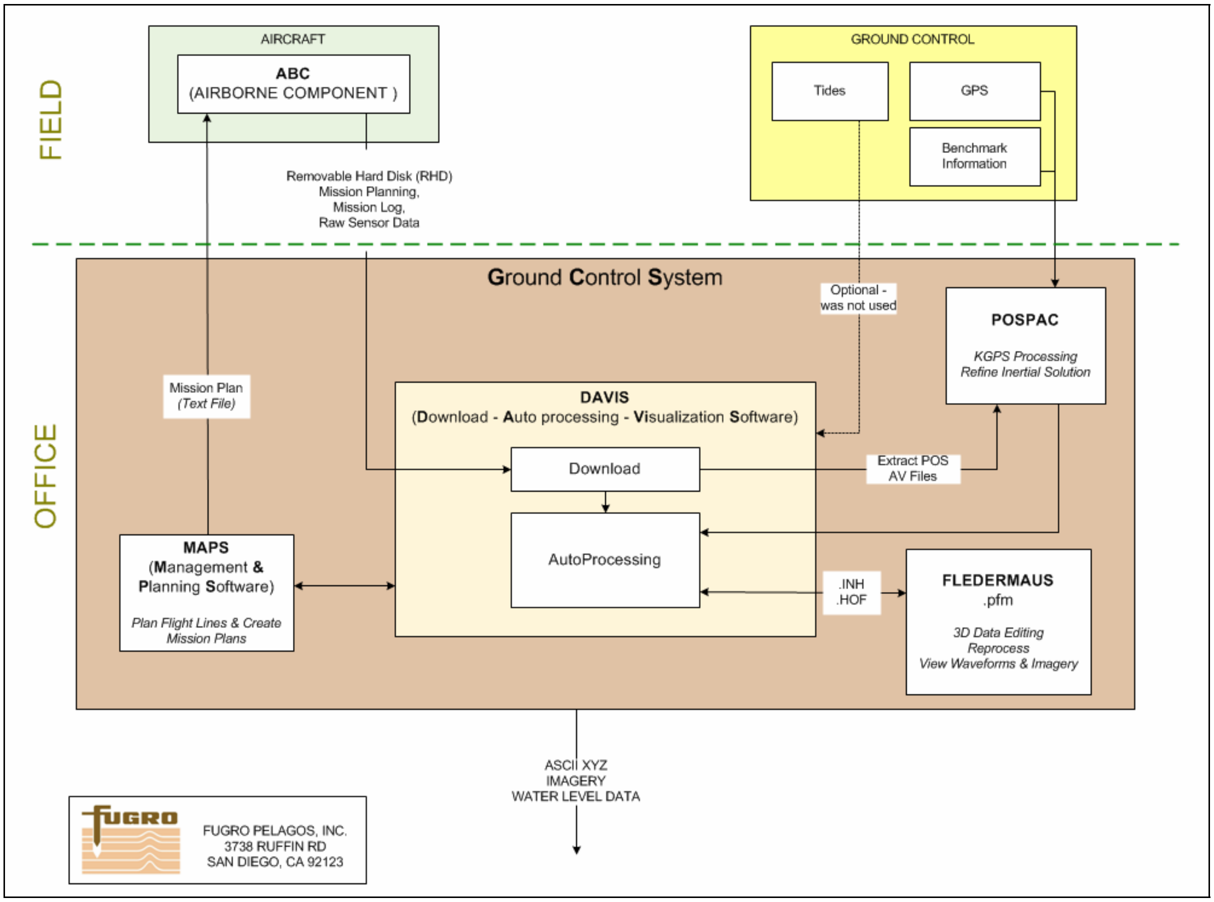


Figure 3-1 Processing Data Flow

3.1 GROUND CONTROL

Dual frequency GPS data collected at each ground station were converted to RINEX format, and uploaded to the National Geodetic Survey (NGS) Online Positioning User Service (OPUS) (http://www.ngs.noaa.gov/OPUS/) for static post-processing. The data were processed by the OPUS using nearby Continuously Operating Reference Stations (CORS) as additional stations in a static network (Table 3-1). Solutions were returned via e-mail.

Table 3-1 CORS Stations Used During OPUS Processing

PID	Designation	Latitude	Longitude	Distance (m)
AF9502	WHD1 WHIDBEY ISLAND 1 CORS ARP	48° 18' 45.760" N	122° 41' 46.055" W	142820.2
AH7396	SEAW SEATTLE WEATHER CORS ARP	47° 41' 13.201" N	122°15' 22.627" W	191876.5

AF9670	SEDR SEDRO WOOLEY DNR CORS ARP	48° 31' 17.591" N	122° 13 25.791" W	178168.9

OPUS solutions for TS0340are given in APPENDIX H, while positions in NAD83 (CORS96) Epoch 2002.00, are provided in Table 3-2.

Table 3-2 Coordinates of Ground Control Positions

	Latitude	Longitude	Ellipsoid Height (m)
TS0340 (OPUS)	48° 22' 0.74789" N	124° 37' 15.66609" W	-15.088
NEA1 (OPUS)	48° 22' 0.93986" N	124° 37' 15.47111" W	-15.115

The GPS receiver on TS0340 (designated T340 for the project) was used as the reference point for the kinematic base station. The T340 average OPUS coordinate solution was used to process the KGPS solution (Section 3.2.2).

3.2 LIDAR DATA

All data were processed using the Optech SHOALS-1000T Ground Control System (GCS) on Windows XP workstations. The GCS includes links to Applanix POSPac software for GPS and inertial processing, and IVS Fledermaus software for data visualization and 3D editing.

The GCS was used to process the KGPS and inertial solutions, apply environmental parameters, auto-process the LIDAR waveforms, apply the vertical datum offsets, edit data and export accepted data to an ASCII file.

3.2.1 PRE-PROCESSING

Once data had been downloaded to DAViS (Download, Auto processing and Visualization Software), hardware related calibration information was entered into the GCS. A list of the calibration values used can be found in APPENDIX I.

In addition to the hardware values, some default environmental parameters were also set. Surface detection method was selected to use the Raman channel initially. If no Raman pick was found then the Infrared would be used, followed by the Green channel.

3.2.2 KGPS PROCESSING

For every mission, a new project was set up in POSPac. POS data downloaded from the air were then extracted from DAViS into the POSPac project. A copy of the native Z-Max ground control files were also copied to the POSPac project directory.

Using POS GPS Version, GPS data from the air and ground control base station were converted from the native NovAtel and Thales GPS formats respectively, to the POS GPS' .gpb format. The KGPS data were then post-processed for position, using the position of T340 given in Table 3-2, as the master control coordinates. Summaries of the GPS processing results can be found in APPENDIX J.

POSPac then used the post-processed GPS positions to post-process the POS orientation data and refine the inertial solution. The final solution was exported to a sbet.out file, which was then used by the GCS during LIDAR auto processing.

3.2.3 AUTO PROCESSING

Once calibration values are set, environmental parameters selected, KGPS zones defined and KGPS data processed, the LIDAR data can be auto processed using the GCS. The auto processing routine contains a waveform processor to select surface and bottom returns from the bathymetry data, and surfaces from the topographic laser. In addition, it contains algorithms to determine position for each laser pulse.

The auto process algorithms obtained inputs from the raw data and calculated a height, position and confidence for each laser pulse. This process, using the set environmental parameters, also performed a first cut at cleaning the data of poor land/seafloor detections. Questionable soundings were flagged as suspect, with attached warning information.

Data were then imported into a project PFM format file to allow data inspection and editing in Fledermaus.

3.2.4 DATA VISUALIZATION & EDITING

Data visualization and editing was done using Fledermaus. Fledermaus was used to view a gridded surface of the entire dataset in 3D (Figure 3-2). Any areas with questionable soundings/elevations were then reviewed using the 3D area-based editor, which displayed each individual sounding in 3D (Figure 3-3). This was used on smaller subsets of the data. Gross fliers were rejected. Other data of uncertain quality requiring more examination were reviewed along with the waveform window, showing shallow and deep channel bottom selections, and IR and Raman surface picks (Figure 3-4). Other metadata such as confidence and warnings are also incorporated into the viewer. In addition, the camera image associated with the laser pulse was also displayed.

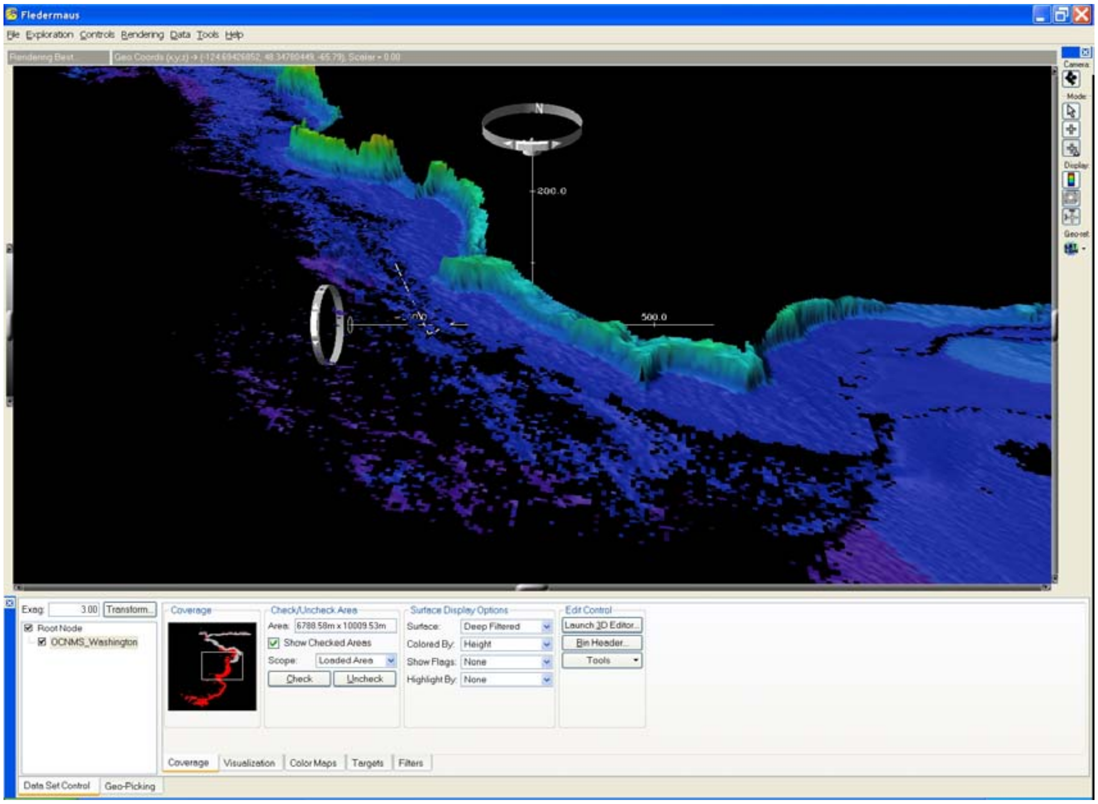


Figure 3-2 Viewing the Dataset Surface in Fledermaus

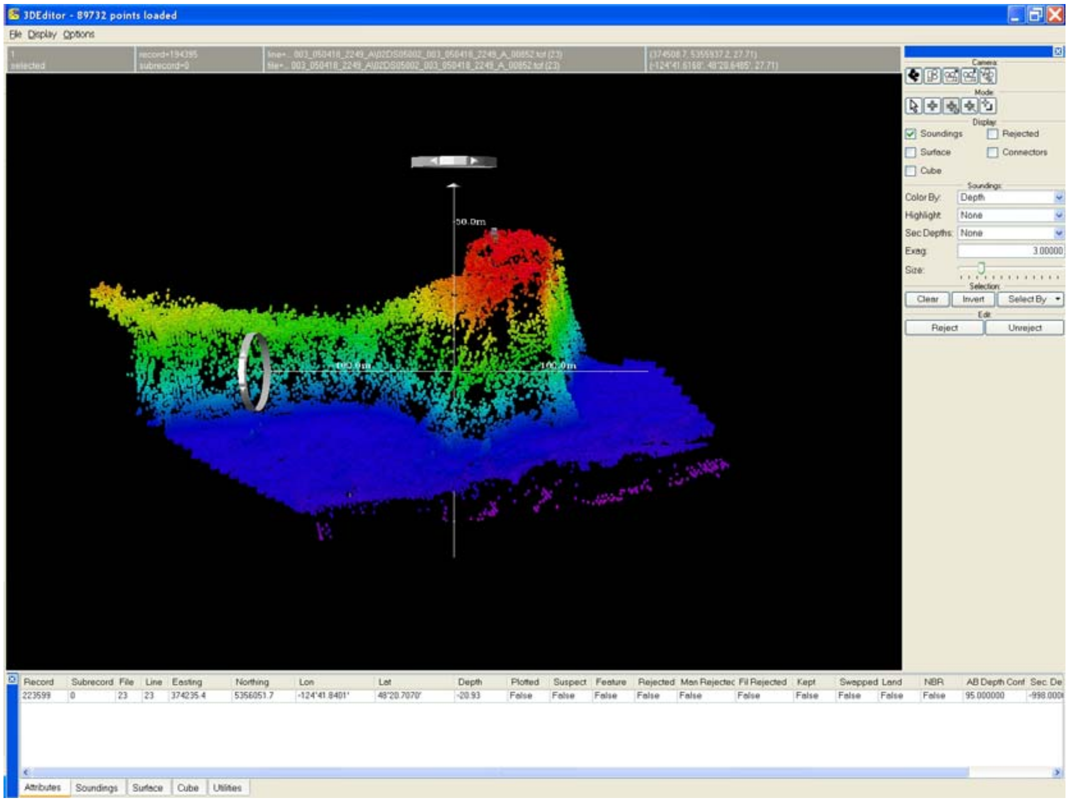


Figure 3-3 Fledermaus 3D Editor

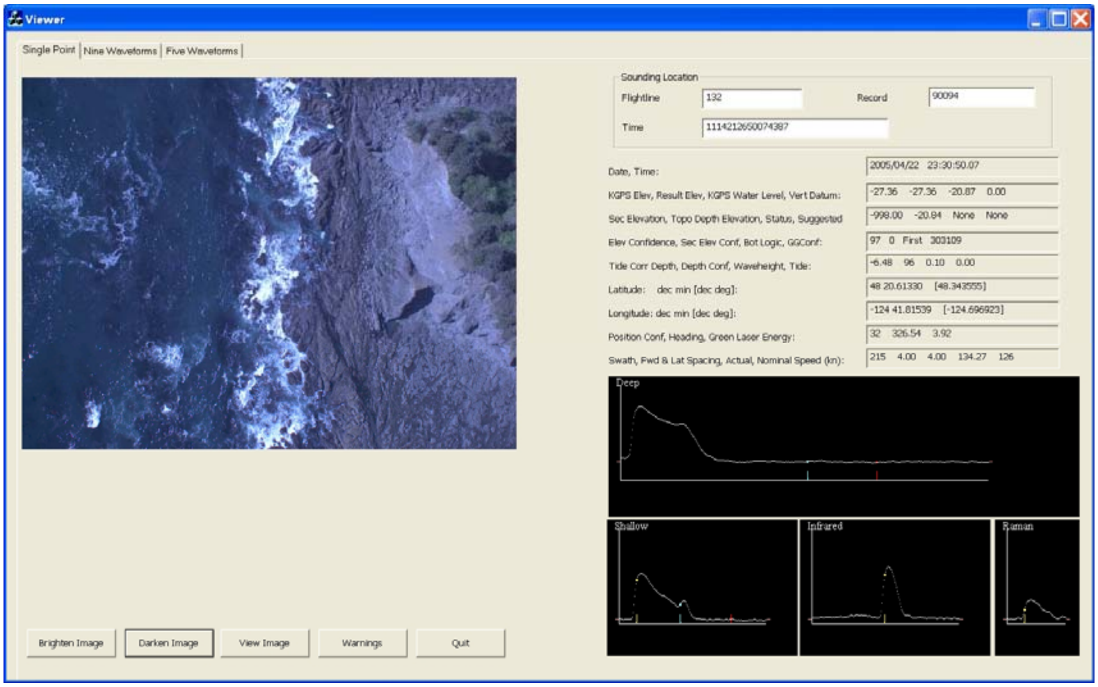


Figure 3-4 Waveform Viewer

Other SHOALS specific tools, such as depth swapping (for handling second depth returns), were used inside Fledermaus.

In general, manual editing was used to remove obvious anomalies in the data mostly due to white water. Returns from the hydro laser over water were mistaken for land and had to be removed. Topographic laser returns from the water surface were also removed.

3.2.5 DTM, CONTOURS, CROSS SECTION & PROFILES

Once all editing was completed in Fledermaus, the GCS was used to export ASCII XYZ files of all remaining accepted data. Exported data were in NAD83 UTM10N in meters, with elevations relative to NAVD88 (Geoid99) in meters.

3.2.6 QUALITY CONTROL

Four tie lines, using the bathymetry laser, were planned and acquired over the survey area. However due to the poor water clarity, most areas of overlap between the tie lines and main survey lines occurred over steep areas of land. Steep and varying terrain does not provide for a good vertical comparison, since small acceptable differences in position can lead to an apparent large vertical difference.

This is noticeable when comparing the 10 kHz topographic laser data to the 1 kHz bathymetric laser data. A difference DTM was created from surfaces of the two datasets in Fledermaus. The difference DTM was then visually inspected. The two laser datasets are comparable in flatter areas, where differences from approximately 0 to 20cm exist. These areas are within the required survey accuracy of +/- 25cm. However, differences between the datasets increase where the terrain becomes more dramatic, as shown in Figure 3-5.

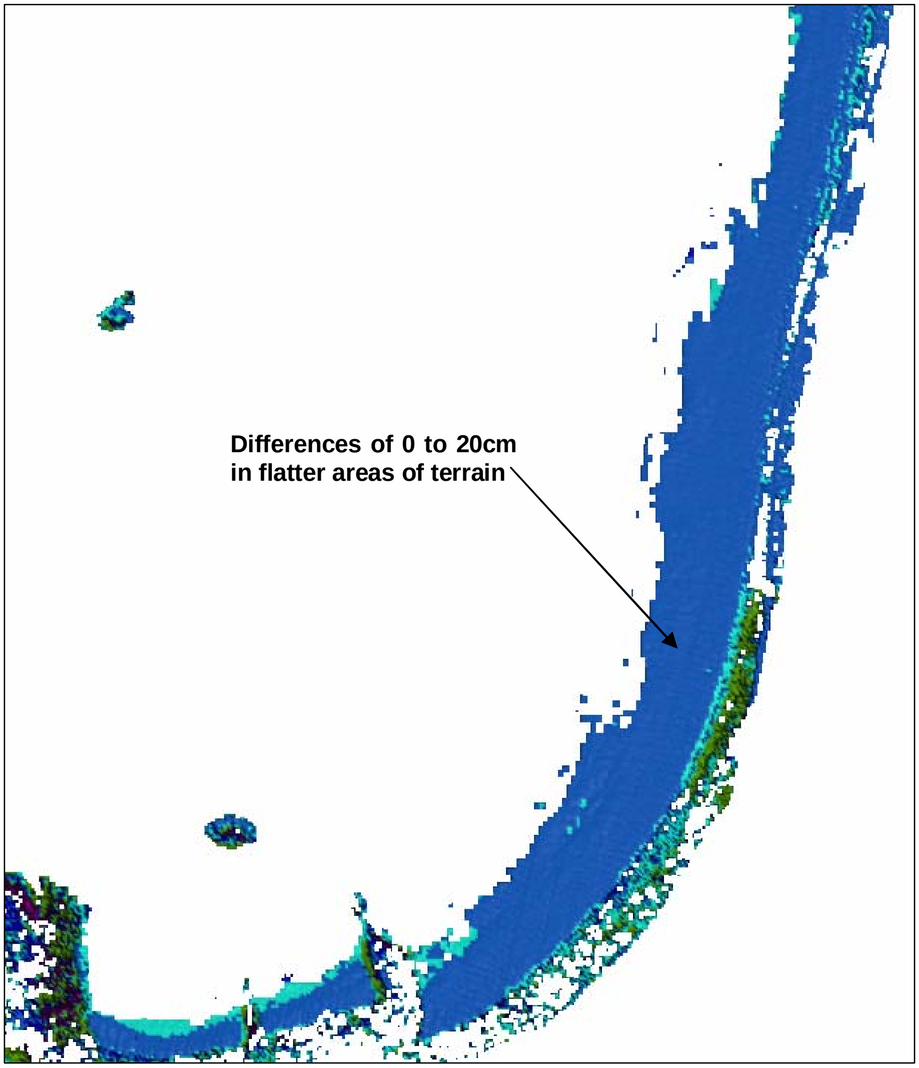


Figure 3-5 Difference Between 1 kHz and 10 kHz Datasets

For the section shown in Figure 3-5, areas of steep terrain were removed and statistics computed. There is a mean difference of 5cm from the 1 kHz to 10 kHz data, with a standard deviation of 22cm in these flatter areas, indicating that data meets the required survey accuracies.

4 CHARTING AND DATA PRODUCTS

After all processing was completed, the following deliverables for the survey were provided:

- ASCII XYZ listing of all accepted data points
- Report :
  - Bathymetric and Topographic LIDAR Acquisition, Northwest Coast Washington (FP-6088.012-RPT-01-00) (Paper, PDF)
- Data Coverage files in Arcview 3.2 shape file format
- Metadata file from CORPSMET95 (Paper, *.met or ***.**gen)

APPENDIX A : DAILY LOG

Date: 17-April-05 Julian Day: 107

GENERAL:

TIME	EVENT
09:30	Dushan A., Pepe M. and Neil K. arrive at Portland. Derek J. already there.
10:30	Depart Portland for Port Angeles.
13:50	Arrive at Port Angeles.
14:30	Move all equipment to room 105 (office).
15:00	Check GPS equipment, load GPS equipment into vehicle.
15:30	Brief Neil K. on Ground Control locations and survey plan.
15:45	Neil K. departs for Neah Bay.
16:00	Continue setting up office.
19:00	Meet with Gene B. (pilot) and brief him on survey plan.
19:10	Received call from Neil K., he located benchmarks and ready to begin work in the morning.
19:30	Dennis T. arrives at hotel.
19:45	Safety meeting and pre-project meeting.

GROUND CONTROL CREW:

TIME	EVENT
	Neil Kussat
14:30	Arrive Port Angeles, set up office and load GPS gear
15:45	Drive to Neah Bay.
18:30	Locate the available control monuments,
19:30	Unpack GPS gear into motel and charge batteries

Date: 18-April-05 Julian Day: 108

FLIGHT SUMMARY:

	ENGINE TIME			PLANE TIME		
	START	STOP	RUN	TAKE OFF	LAND	FLYING
FLIGHT 01	07:30	11:16	3h 46m	08:20	11:13	2h 53m
FLIGHT 02	14:20	18:00	3h 40m	14:34	17:58	3h 24m
	DAILY TOTAL		7h 26m	**DAILY TOTAL**		6h 17m
	PROJECT TO DATA		7h 26m	**PROJECT TO DATE**		6h 17m

GENERAL:

TIME	EVENT
06:15	Received call from Neil K. weather looks good for flying.
06:30	Dushan A., Derek J. and Dennis T. depart for airport.
07:00	Completed OmniStar changes to West coast settings.
07:45	Received call from Dennis T. having trouble with Airborne system initialization.
08:15	Some cable connections on the Airborne system had come loose during transit. All connections tightened and system operational.
10:30	Received call from Dennis T. indicating they were not getting any data, informed

TIME	EVENT
	to abort mission.
11:30	Received data from Airborne system.
11:45	Having trouble reading RHD, external hard drive not configured correctly. Bypass connections and got reader to work.
12:15	Downloading and auto-processing data.
13:00	As per suspicion data very sparse.
14:30	Downloaded GPS data from FTP site
15:30	Processing KGPS data, very high PDOP spike in data. This was not reported in the planning software.
16:30	Internet connection down.
18:30	Received data from Airborne crew.
18:45	Downloading and auto-processing data.
20:00	Topo data looks good.
20:10	Internet connection not working to get GPS data fro FTP site. To be checked in the morning.

AIRBORNE CREW:

TIME	EVENT
	Dennis Tobin, Derek Johnson
06:15	Safety meeting @ hotel.
06:30	Depart hotel for airport.
06:45	Arrive @ airport.
07:00	Reprogram Omin Star in airborne system.
07:30	Start Engines.
07:40	Rebooting system due to problem with system not initializing.
07:50	Cleaning fiber optic data cable and checking other cable connections.
08:25	System working and ready for takeoff.
11:16	Stop engines.
11:25	Depart airport for hotel.
13:30	Depart hotel for airport.
13:45	Arrive @ airport.
14:20	Start engines.
15:25	Rebooting System due to problem with network connection.
15:35	Rebooting System network restored but can’t get POS to lock.
15:46	Flying POS Initialization line.
18:00	Stop engines.
18:20	Depart airport for hotel.

GROUND CONTROL CREW:

TIME	EVENT
	Neil Kussat
0615	Phone Dushan and report on weather.
0620	Set up GPS receivers (primary and secondary) at TS0340.

TIME	EVENT
0730	Prepare site descriptions, DPR, etc.
1325	Shutdown receivers and download data from primary receiver, re-start receivers, ftp data to Port Angeles.
1900	Shut down and tear down GPS receivers. Download data from both receivers and compress,

Date: 19-April-05 Julian Day: 109

FLIGHT SUMMARY:

	ENGINE TIME			PLANE TIME		
	START	STOP	RUN	TAKE OFF	LAND	FLYING
FLIGHT 01	06:52	07:52	1h 00m	07:04	07:50	0h 46m
FLIGHT 02	10:20	13:09	2h 49m	10:42	13:00	2h 18m
	DAILY TOTAL		3h 49m	**DAILY TOTAL**		3h 04m
	PROJECT TO DATE		11h 15m	**PROJECT TO DATE**		9h 21m

GENERAL:

TIME	EVENT
07:30	Received call from Dennis T. indicating that they cannot fly due to a marine layer.
09:30	Received call from Neil K. indicating the GPS data from previous day was on FTP site. Also checked with him on weather and conditions are ok for flying.
09:45	Advised airborne crew to prepare for a 10:15 wheels up.
10:00	Download GPS data from FTP site.
10:30	Process GPS data from previous day.
13:30	Received data from Airborne crew.
13:45	Downloading and auto-processing data.
14:15	Checking data from today's flight before client arrives.
15:30	Client arrives at hotel. Show client some Topo data collected yesterday. Also showed him a very small patch of Hydro data. We also collected 2 lines of hydro data on the transit to Neah Bay (in the Strait) which shows very good data. I also showed this to the client so he knows we are unable to get any data on site due to water clarity.
16:30	Taking client to the plane to show him the airborne system.
17:30	Completed system tour with client.
18:00	Continue processing data.

AIRBORNE CREW:

TIME	EVENT
	Dennis Tobin, Derek Johnson
06:00	Safety meeting @ hotel.
06:15	Depart hotel for airport.
06:30	Arrive @ airport.
06:52	Start Engines.
07:30	Arrive on location and due to a heavy marine layer returning to airport.

TIME	EVENT
07:52	Stop engines.
08:10	Depart airport for hotel.
10:00	Depart hotel for airport.
10:20	Start Engines.
11:00	Arrive on location and start survey.
12:29	Finish survey and heading back to airport due to water clarity still dirty.
13:09	Stop engines.
13:15	Depart airport for hotel.
14:30	Depart hotel for airport.
14:45	Arrive @ airport and start checking system cables and cleaning laser bay window.
17:00	Depart airport for hotel.

GROUND CONTROL CREW:

TIME	EVENT
	Neil Kussat
0630	Set-up primary and secondary receivers at control monument
0900	FTP previous days data to Port Angeles
1730	Stop logging, tear down, download and compress data
1830	FTP data to Port Angeles

Date: 20-April-05 Julian Day: 110

GENERAL:

TIME	EVENT
07:30	Received call from Neil K. indicating that there is a Marine layer along the coast line at Neah Bay.
08:05	Received update from another plane going towards Neah Bay, still fogged in.
08:15	Received call from Neil K. still fogged in.
09:30	Received call from Neil K. indicating the fog had got worse. Instructed Neil to also drive around the point of Cape Flattery to check the conditions along the coast.
10:00	Pepe M. working on GPS processing with Derek J.
10:10	Conditions along the coast are the same as in Neah Bay.
13:00	Another update received from Neil K. at Neah Bay, conditions still not suitable for flying.
13:30	Continue with procedures GPS processing.
15:00	Another update received from Neil K. at Neah Bay, conditions still not suitable for flying.
17:00	Another update received from Neil K. at Neah Bay, conditions still not suitable for flying.
17:10	Called off flights for the day, since it is unable to fly the site at night. The terrain surrounding the site is too high for night operations.

AIRBORNE CREW:

TIME	EVENT
	Dennis Tobin, Derek Johnson
06:00	Safety meeting @ hotel.
06:15	Depart hotel for airport.
06:30	Arrive @ airport. Awaiting word from Neil on weather conditions at survey area.
07:00	Returning to hotel weather at survey poor.
07:15	Arrive back at hotel, start on operating procedures for airborne system.
09:30	Depart hotel for airport.
09:45	Arrive @ airport. Awaiting word from Neil on weather conditions at survey area.
10:15	Returning to hotel weather at survey poor.
10:30	Arrive back at hotel; continue on operating procedures for airborne system.
12:30	Depart hotel for airport.
12:45	Arrive @ airport. Awaiting word from Neil on weather conditions at survey area.
13:00	Returning to hotel weather at survey poor.
13:15	Arrive back at hotel, continue on operating procedures for airborne system.
15:00	Received word from Neil weather still bad.
17:00	Received word from Neil weather still bad.

GROUND CONTROL CREW:

TIME	EVENT
	Neil Kussat
07:25	Phone Port Angeles with weather report
07:45	Set up GPS receivers
08:15	Phone in weather report
09:15	Phone in weather report
10:30	Drive to western side of the peninsula and check on weather condition
11:00	Phone in weather report
14:30	Drive to western side of the peninsula and check on weather condition. Phone in weather report
16:30	Drive to western side of the peninsula and check on weather condition. Phone in weather report
17:00	Secure GPS operations

Date: 21-April-05 Julian Day: 111

GENERAL:

TIME	EVENT
07:30	Internet access is down unable to check weather.
07:45	Internet access is back, satellite imagery does not look good.
08:00	Received call from Neil K. indicating that there is a Marine layer along the coast line at Neah Bay.
10:00	Received call from Neil K. indicating that there is a Marine layer along the coast line at Neah Bay.
12:00	Received call from Neil K. indicating that there is a Marine layer along the coast line at Neah Bay.

TIME	EVENT
14:00	Received call from Neil K. indicating that there is a Marine layer along the coast line at Neah Bay.
16:00	Received call from Neil K. indicating that there is a Marine layer along the coast line at Neah Bay.
16:30	Sent Derek J. to Neah Bay to pickup extra GPS receiver.
17:00	Called off flights for the day due to weather.

AIRBORNE CREW:

TIME	EVENT
	Dennis Tobin, Derek Johnson
06:30	Safety meeting @ hotel.
07:00	Received word from Neal on weather conditions at survey area poor.

GROUND CONTROL CREW:

TIME	EVENT
	Neil Kussat
07:30	Drive to western side of the peninsula and check on weather condition. Phone in weather report
09:30	Drive to western side of the peninsula and check on weather condition. Phone in weather report
11:30	Drive to western side of the peninsula and check on weather condition. Phone in weather report
13:30	Drive to western side of the peninsula and check on weather condition. Phone in weather report
15:30	Drive to western side of the peninsula and check on weather condition. Phone in weather report
16:50	FTP GPS data from previous day, ant ht log, and DPR to Port Angeles

Date: 22-April-05 Julian Day: 112

FLIGHT SUMMARY:

	ENGINE TIME			PLANE TIME		
	START	STOP	RUN	TAKE OFF	LAND	FLYING
FLIGHT 01	09:26	10:30	1h 04m	09:42	10:28	0h 46m
FLIGHT 02	13:49	18:30	4h 41m	13:55	18:27	4h 32m
	DAILY TOTAL		5h 45m	**DAILY TOTAL**		5h 18m
	PROJECT TO DATE		17h 00m	**PROJECT TO DATE**		14h 39m

GENERAL:

TIME	EVENT
07:30	Weather satellite (GOES) looks reasonable, informed airborne crew to head to the airport and be ready for flight.
07:45	Received call from Neil K. indicating that there is a Marine layer along the coast line at Neah Bay. The layer is very small and he thinks it will burn off soon as the sun is shining through.
08:00	Informed airborne crew to hold off for an hour before taking off.

TIME	EVENT
08:45	Received call from Neil K. indicating some patches are clear.
09:00	Informed airborne crew to take off at 09:15 and fly where possible.
10:00	Received call from Dennis T. indicating there is no clear patches large enough to fly any lines.
11:00	Informed Neil to give another weather update at 11:45.
11:45	Received call from Neil K. starting to clear up even more, another update at 12:30.
12:30	Received another call from Neil K. Looks like another patch of fog had moved in. Looking at the satellite image it shows the patch moving out fast. Should be clear by 14:00.
13:30	Received update from Neil K. area looks clear.
13:40	Instructed airborne crew to leave for site and collect data.
19:00	Received data from airborne crew.
19:15	Downloading and auto-processing data.
20:30	Checking data, coverage is about 50% on the North half of the area. The lack of data is due to water clarity and in many cases kelp in the water. Dark patches of kelp are visible in the water column.

AIRBORNE CREW:

TIME	EVENT
	Dennis Tobin, Derek Johnson
07:00	Safety meeting @ hotel.
07:15	Received word from Neal on weather conditions at survey area poor.
08:00	Depart hotel for airport.
08:15	Arrive @ airport. Awaiting word from Neal on weather conditions at survey area.
09:00	Received word from Neal on weather conditions at survey area starting to clear.
09:26	Start Engines.
10:07	Arrive on location and due to a heavy marine layer returning to airport.
10:30	Stop engines.
10:45	Depart airport for hotel.
12:30	Depart hotel for airport.
12:45	Arrive @ airport. Received word from Neal that weather conditions at survey area still not good enough to fly.
13:49	Start Engines.
14:00	Arrive on location and start survey.
18:30	Stop engines.
18:40	Depart airport for hotel.

GROUND CONTROL CREW:

TIME	EVENT
	Neil Kussat
07:15	Drive to western side of the peninsula and check on weather condition. Phone in weather report
08:30	Set-up GPS control (T340 and NEA1), commence logging.

TIME	EVENT
09:20	Drive to western side of the peninsula and check on weather condition. Phone in weather report
11:20	Drive to western side of the peninsula and check on weather condition. Phone in weather report
12:20	Drive to western side of the peninsula and check on weather condition. Phone in weather report
19:00	Secure GPS ops.
19:30	Download data, compress, and FTP to Port Angeles

Date: 23-April-05 Julian Day: 113

FLIGHT SUMMARY:

	ENGINE TIME			PLANE TIME		
	START	STOP	RUN	TAKE OFF	LAND	FLYING
FLIGHT 01	09:18	11:57	2h 39	09:28	11:54	2h 26m
FLIGHT 02						
	DAILY TOTAL		2h 39m	**DAILY TOTAL**		2h 26m
	PROJECT TO DATE		19h 39m	**PROJECT TO DATE**		17h 05m

GENERAL:

TIME	EVENT
07:30	Weather satellite (GOES) looks reasonable, will delay take off since tide is at lowest in the morning.
08:00	Received call from Neil K. conditions look ok for flying.
09:00	Instructed airborne crew to take off and try collecting data in the Southern half of the area.
10:15	Creating document showing data coverage of area.
11:00	Unable to get any GPS data as it cannot be FTP. The center at Neah Bay is closed for the weekend.
12:35	Received data from airborne data.
12:45	Downloading and auto-processing data.
14:00	Checking the data from morning flight. Unable to collect data in the southern half of the southern area due to low cloud cover.
15:00	Checking the weather conditions but unable to fly due to low cloud cove.
15:30	Continue on coverage document.
19:00	Email coverage info to San Diego.

AIRBORNE CREW:

TIME	EVENT
	Dennis Tobin, Derek Johnson
08:00	Safety meeting @ hotel.
08:30	Depart hotel for airport.
09:18	Start Engines.
09:54	Arrive on location and start survey.
11:57	Stop engines.

TIME	EVENT
12:10	Depart airport for hotel.
14:30	Depart hotel for airport.
14:45	Arrive @ airport. To perform maintenance on system.
16:00	Finish changing desiccant in sensor head and laser, purging system with nitrogen
16:15	Depart airport for hotel.

GROUND CONTROL CREW:

TIME	EVENT
	Neil Kussat
07:30	Drive to western side of the peninsula and check on weather condition. Phone in weather report
08:00	Set-up GPS control (T340 and NEA1), commence logging
10:00	Attempt to ftp data from museum. Partially successful.
12:45	Drive to western side of the peninsula and check on weather condition. Phone in weather report
14:00	Phone in weather report, drive back to Neah Bay
15:00	Secure GPS ops
15:30	Download data

Date: 24-April-05 Julian Day: 114

FLIGHT SUMMARY:

	ENGINE TIME			PLANE TIME		
	START	STOP	RUN	TAKE OFF	LAND	FLYING
FLIGHT 01	11:17	15:32	4h 15m	11:25	15:28	4h 03m
FLIGHT 02						
	DAILY TOTAL		4h 15m	**DAILY TOTAL**		4h 03m
	PROJECT TO DATE		23h 54m	**PROJECT TO DATE**		21h 08m

GENERAL:

TIME	EVENT
07:30	Weather satellite (GOES) looks reasonable, waiting on update from Neil K. from site.
08:00	Called Neil K. who indicated that it was raining in Neah Bay.
08:30	Waiting on weather conditions to clear.
09:00	Pepe working on Power/Timing processing and documents.
09:30	Received another update from Neil K. the rain has stopped but some cloud cover still exists. He is unable to see the section we need to fly due to the terrain and the lack of roads to get there.
10:00	Checking the satellite weather and the ceiling seems to be getting better.
10:30	Airborne crew heading to plane to flight preparation.
10:50	Received another update from Neil K. indicating that it is clearing up.
11:00	Instructed airborne crew to try the flying the mission.
16:00	Received data from airborne crew.

TIME	EVENT
16:15	Downloading and auto-processing data.
17:30	The southern area flown did not produce very many depths. It looks like collecting more data within the next week is not going to produce much better results.
21:00	Received call from Mark M. indicating that we were to relocate to Yakima in the morning.

AIRBORNE CREW:

TIME	EVENT
	Dennis Tobin, Derek Johnson
07:45	Safety meeting @ hotel.
08:00	Received word from Neal on weather conditions at survey area poor.
10:30	Received word from Neal on weather conditions at survey area starting to clear.
10:45	Depart hotel for airport.
11:00	Arrive @ airport.
11:17	Start Engines.
11:50	Arrive on location and start survey.
15:32	Stop engines.
15:45	Depart airport for hotel.

GROUND CONTROL CREW:

TIME	EVENT
	Neil Kussat
07:30	Drive to western side of the peninsula and check on weather condition. Phone in weather report
09:30	Drive to western side of the peninsula and check on weather condition. Phone in weather report
10:00	Set-up GPS control (T340 and NEA1)
10:30	Drive to western side of the peninsula and check on weather condition. Phone in weather report
16:00	Download data and update logs

APPENDIX B : GROUND CONTROL EQUIPMENT

THALES NAVIGATION

SUPERIOR RTK PERFORMANCE IN A MODULAR DESIGN

Z-Max Surveying System

The Z-Max™ surveying system from Thales Navigation is a precision GPS surveying solution designed for topography and construction. Offering superior RTK performance, an innovative design and a total software solution, Z-Max delivers survey grade positioning on demand.

Superior RTK Performance

Z-Max rises above other GPS receivers with ADAPT-RTK™. This breakthrough technology dramatically expands centimeter-accurate coverage by rapidly adapting to current conditions. With ADAPT-RTK, Z-Max ensures exceptional RTK coverage and data confidence. Z-Max is capable of using VRS and FKP, so that optimal results can be obtained in networks of reference stations.

Innovative Modular Design

Z-Max features a unique modular design, with interchangeable base and rover receivers, for quick and easy system optimization in the field. The versatile system offers options for power, portability, communications, data collection, downloading and post-processing.

Wireless Roving: Integrated Bluetooth™ advanced wireless system enables a convenient cable-free RTK rover.

Long-Range Communication: UHF or cellular – or a uniquely combined UHF + GSM module – simply snap into place.

New Vortex™ UHF Antenna: Breakthrough technology eliminates conventional radio antennas and cables.

On-Board Software: A full range of options are available, including control, stop and go, RTK setup and data collection – all without the need of an additional field controller.

The Total Surveying Solution

The Z-Max system leverages the latest in surveying technology by integrating field and office software solutions focused on topographic and construction surveying. With this comprehensive suite of software tools, the Z-Max total surveying solution can enhance your surveying capabilities, boost your productivity, improve your data quality, and upgrade your deliverables.

FAST Survey™ software is a powerful graphical field companion to Z-Max that enables feature coding, real-time line work, coordination of system setup, COGO (Coordinate Geometry) and seamless connectivity to a variety of optical total stations – all available through a simple touch-screen menu.

GNSS Studio™ software is the Z-Max GPS surveying office manager, intuitively guiding you through the entire GPS data collection process, from planning to professional quality deliverables.

www.thalesnavigation.com

THALES NAVIGATION

Z-MAX SURVEYING SYSTEM

TECHNICAL SPECIFICATIONS

Features	Benefits
ADAPT-RTK. Automatic Decorrelation and Parameter Tuning.	Adapts to different environments to maximize coverage area of centimeter-accurate solutions for RTK. Two second initialization (typical) baselines <20 km (12 miles) centimeter-level solution availability up to 50 km (31 miles) in long-range mode.
Z-Max modular design	Tripod mounted data collection, cable-free RTK rover and RTK rover with a backpack, all with the same GPS receiver platform.
On-Board control software	Perform control, topo and even RTK surveys all without the need for additional field computer and software.
Integrated software solution for Topography and Construction	Move jobs from planning through deliverable with GNSS Studio office software and FAST Survey field software.
Bluetooth wireless connectivity	Eliminates the cost and hassles of cables.
Modular Communications technology	Flexible communications options, including Thales UHF, Pacific Crest UHF, GSM cellular and GSM plus UHF, are modular and simply snap on to the Z-Max.
Vortex UHF antenna technology	UHF antenna integrated with range pole provides superior range and physical durability.
Modular, lithium-ion power technology -14 hour size - 7 hour size	Smart battery system provides long runtime, an integral charger and up-to-the-minute capacity information and reliable, trouble-free operation.
Dual-frequency GPS all-in-view operation	Maximize GPS measurement redundancy for surveying by tracking all observables of all GPS satellites visible above the horizon.
P-Code decryption using patented Z-tracking™ technique	The cleanest signal quality commercially available for civilian use.
Automatic multipath mitigation	Robust operation in real-world surveying environments.
Reference station network compatibility	Using the VRS or FKP positioning, Z-Max obtains optimal results from networks of reference stations in seconds.

Performance Specifications

Static, Rapid Static *
- Horizontal 0.005 m + 0.5 ppm (0.016 ft + 0.5 ppm)
- Vertical 0.010 m + 0.5 ppm (0.033 ft + 0.5 ppm)

Post-Processed Kinematic
- Horizontal 0.010 m + 1.0 ppm (0.033 ft +1.0 ppm)
- Vertical 0.020 m + 1.0 ppm (0.065 ft +1.0 ppm)

Real-Time DGPS position
- < 0.8 m (2.62 ft)

Real-Time Kinematic Position (fine mode)
- Horizontal 0.010 m + 1.0 ppm (0.033 ft + 1.0 ppm)
- Vertical 0.020 m + 1.0 ppm (0.065 ft + 1.0 ppm)

ADAPT-RTK Initialization
- 99.9% reliability
- Typical 2 second initialization for baselines < 20 km

Technical Specifications

GPS Receiver Environmental
- Meets IP54 for moisture *
- Operating temperature: -30° to +55°C (-22° to +131°F)
- Storage temperature: -40° to +85°C (-40° to +185°F)
- Shock: 1.5 m (4.92 ft) pole drop
- Vibration: MIL-STD-810F Method 514.4 (I-3.1.1, I-3.4.8, I-3.4.9) *

Physical
- Receiver Module: 1.371 kg (3.02 lb)
- Antenna Module: 0.64 kg (1.17 lb)
- Power Module: 0.52 kg (0.96 lb)

Power *
- 9-24 VDC input
- 10-24 VDC output on serial ports
- Max-Run battery > 14 hrs. run-time @ 0 ºC
- Max-Lite battery > 7 hrs. run-time @ 0 ºC

Memory
- 48 hours of 1 sec. raw GPS data with 64 MB Secure digital
- 128 MB SD card available

Languages Supported in Controller
- English
- French
- German
- Portuguese
- Spanish

Standard Features
- Dual frequency with Z-Tracking
- On-board controller software
- 10 Hz Data recording

Optional System Components
- Thales Navigation UHF Communication Module
- Pacific Crest UHF Communication Module
- GSM Communication Module
- GSM+UHF Communication Module
- Z-Max GPS Antenna
- Padded Carry Bag
- Hard Shell Case

System Software

GNSS Studio Office Software
- L1 Processing
- RTK Support
- L1 + L2 Processing Option

FAST Survey Field Software
- GPS Control
- Optical Instrument Control
- Advanced Road Construction (optional)

Performance values assume minimum of 5 satellites, following the procedures recommended in the product manual. High-multipath areas, high PDOP values and periods of severe atmospheric conditions may degrade performance.

**Based on preliminary tests.*

Thales Navigation, Inc.
Corporate Headquarters, Santa Clara, CA, USA
+1 408 615 5100 • Fax +1 408 615 5200
Toll Free (Sales in USA/Canada) 1 800 922 2401
Email professionalsales@thalesnavigation.com
In South America +56 2 234 56 43 • Fax +56 2 234 56 47
In China +86 10 6566 9866 • Fax +86 10 6566 0246
Web site www.thalesnavigation.com

Thales Navigation follows a policy of continuous product improvement; specifications and descriptions are thus subject to change without notice. **Please contact Thales Navigation for the latest product information.**

THALES NAVIGATION

APPENDIX C : NGS DATASHEET (TS0340)

```
Data Sheet RetrievalThe NGS Data Sheet
DATABASE = Sybase ,PROGRAM = datasheet, VERSION = 7.16
1        National Geodetic Survey,   Retrieval Date = APRIL 15, 2005
 TS0340 ***********************************************************************
 TS0340  CBN          -  This is a Cooperative Base Network Control Station.
 TS0340  TIDAL BM     -  This is a Tidal Bench Mark.
 TS0340  DESIGNATION -  944 3090 A TIDAL
 TS0340  PID          -  TS0340
 TS0340  STATE/COUNTY-  WA/CLALLAM
 TS0340  USGS QUAD    -  NEAH BAY (1984)
 TS0340
 TS0340                         *CURRENT SURVEY CONTROL
 TS0340  ___________________________________________________________________
 TS0340* NAD 83(1998)-  48 22 00.74511(N)    124 37 15.66974(W)     ADJUSTED
 TS0340* NAVD 88     -         5.675  (meters)      18.62   (feet)  ADJUSTED
 TS0340  ___________________________________________________________________
 TS0340  X            -  -2,411,951.484 (meters)                    COMP
 TS0340  Y            -  -3,493,580.024 (meters)                    COMP
 TS0340  Z            -   4,744,064.346 (meters)                    COMP
 TS0340  LAPLACE CORR-           9.06  (seconds)                    DEFLEC99
 TS0340  ELLIP HEIGHT-         -15.15  (meters)           (07/03/01) GPS OBS
 TS0340  GEOID HEIGHT-         -20.85  (meters)                     GEOID03
 TS0340  DYNAMIC HT  -           5.676 (meters)      18.62  (feet)  COMP
 TS0340  MODELED GRAV-     980,914.3   (mgal)                       NAVD 88
 TS0340
 TS0340  HORZ ORDER  -  B
 TS0340  VERT ORDER  -  FIRST     CLASS II
 TS0340  ELLP ORDER  -  FIFTH     CLASS I
 TS0340
 TS0340.The horizontal coordinates were established by GPS observations
 TS0340.and adjusted by the National Geodetic Survey in July 2001.
 TS0340.This is a SPECIAL STATUS position.  See SPECIAL STATUS under the
 TS0340.DATUM ITEM on the data sheet items page.
 TS0340
 TS0340.The orthometric height was determined by differential leveling
 TS0340.and adjusted by the National Geodetic Survey in July 2002.
 TS0340
 TS0340.This Tidal Bench Mark is designated as VM 1109
 TS0340.by the Center for Operational Oceanographic Products and Services.
 TS0340
 TS0340.The X, Y, and Z were computed from the position and the ellipsoidal ht.
 TS0340
 TS0340.The Laplace correction was computed from DEFLEC99 derived deflections.
 TS0340
 TS0340.The ellipsoidal height was determined by GPS observations
 TS0340.and is referenced to NAD 83.
 TS0340
 TS0340.The geoid height was determined by GEOID03.
 TS0340
 TS0340.The dynamic height is computed by dividing the NAVD 88
 TS0340.geopotential number by the normal gravity value computed on the
 TS0340.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 TS0340.degrees latitude (g = 980.6199 gals.).
 TS0340
 TS0340.The modeled gravity was interpolated from observed gravity values.
 TS0340
 TS0340;                    North         East     Units Scale Factor Converg.
 TS0340;SPC WA N     -   158,878.614   219,479.318   MT  0.99995168   -2 49 12.0
 TS0340;UTM  10      - 5,358,347.555   379,940.928   MT  0.99977710   -1 12 42.2
 TS0340
 TS0340!             -  Elev Factor  x  Scale Factor =   Combined Factor
 TS0340!SPC WA N     -   1.00000237  x   0.99995168  =   0.99995405
 TS0340!UTM  10      -   1.00000237  x   0.99977710  =   0.99977947
```

```
TS0340
TS0340                          SUPERSEDED SURVEY CONTROL
TS0340
TS0340  NAD 83(1991)-  48 22 00.74634(N)    124 37 15.66839(W) AD(       ) B
TS0340  ELLIP H (01/27/00)  -15.13   (m)                       GP(       ) 4 1
TS0340  NAD 83(1991)-  48 22 00.74183(N)    124 37 15.67186(W) AD(       ) B
TS0340  ELLIP H (05/29/91)  -14.96   (m)                       GP(       ) 4 1
TS0340  NAD 83(1986)-  48 22 00.73707(N)    124 37 15.68106(W) AD(       ) 1
TS0340  NAVD 88 (01/27/00)    5.67   (m)           18.6    (f) LEVELING    3
TS0340  NGVD 29 (06/19/89)    4.54   (m)           14.9    (f) LEVELING    3
TS0340
TS0340.Superseded values are not recommended for survey control.
TS0340.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
TS0340.See file dsdata.txt to determine how the superseded data were derived.
TS0340
TS0340_U.S. NATIONAL GRID SPATIAL ADDRESS: 10UCU7994158348(NAD 83)
TS0340_MARKER: DD = SURVEY DISK
TS0340_SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT
TS0340_SP_SET: METAL ROD DRIVEN INTO GROUND
TS0340_STAMPING: 3090 A 1982
TS0340_MARK LOGO: NOS
TS0340_MAGNETIC: N = NO MAGNETIC MATERIAL
TS0340_STABILITY: A = MOST RELIABLE AND EXPECTED TO HOLD
TS0340+STABILITY: POSITION/ELEVATION WELL
TS0340_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
TS0340+SATELLITE: SATELLITE OBSERVATIONS - September 11, 1999
TS0340
TS0340  HISTORY     - Date     Condition        Report By
TS0340  HISTORY     - UNK      MONUMENTED
TS0340  HISTORY     - 1987     GOOD             NGS
TS0340  HISTORY     - 19890728 GOOD             NGS
TS0340  HISTORY     - 19910225 GOOD
TS0340  HISTORY     - 19980630 GOOD             NGS
TS0340  HISTORY     - 19990911 GOOD             NOS
TS0340
TS0340                          STATION DESCRIPTION
TS0340
TS0340'DESCRIBED BY NATIONAL GEODETIC SURVEY 1987 (MRM)
TS0340'THE STATION WAS RECOVERED AT THIS DATE.
TS0340'
TS0340'THE STATION IS LOCATED IN THE WESTERN SECTION OF NEAH BAY, AT AN
TS0340'INDIAN BURIAL AREA.
TS0340'
TS0340'TO REACH THE STATION FROM THE POST OFFICE AND STORE IN NEAH BAY, GO
TS0340'WEST FOR 0.3 KM (0.2 MI) ON MAIN STREET TO THE STATION ON THE
TS0340'RIGHT, AT THE WEST END OF A FENCE-ENCLOSED AREA.
TS0340'
TS0340'THE STATION IS A STANDARD NOS DISK
TS0340'STAMPED---3090A 1982---,
TS0340'CRIMPED TO THE TOP OF A GALVANIZED STEEL ROD RECESSED 23 CM BELOW
TS0340'GROUND ENCASED IN A 4-INCH PVC PIPE WITH SCREW CAP.  LOCATED
TS0340'4.7 METERS (15.5 FT) NORTH FROM THE APPROXIMATE CENTER OF STATE
TS0340'HIGHWAY 112,
TS0340'1.8 METERS (6 FT) WEST FROM A WOODEN FENCE,
TS0340'0.8 METERS (2.5 FT) WEST-NORTHWEST FROM A TELEPHONE POLE AND
TS0340'0.9 METERS (3 FT) SOUTH-SOUTHWEST FROM A WITNESS POST.
TS0340'
TS0340'WASHINGTON DOT, FAA, TIDE STATIONS - 1987.
TS0340'
TS0340'THIS STATION SUITABLE FOR GPS SURVEYS.
TS0340'
TS0340'DESCRIBED BY D.A. WEGENAST.
TS0340
```

```
TS0340                          STATION RECOVERY (1989)
TS0340
TS0340'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1989
TS0340'THE STATION IS LOCATED ABOUT 49.9 KM (31.0 MI) NORTH-NORTHWEST OF
TS0340'FORKS, 40.2 KM (25.0 MI) NORTHWEST OF SAPHO, 30.6 KM (19.0 MI) WEST
TS0340'OF CLALLAM BAY AND IN THE WESTERN SECTION OF THE CITY OF NEAH BAY.
TS0340'TO REACH FROM THE POST OFFICE IN NEAH BAY, GO WEST ON MAIN STREET FOR
TS0340'0.32 KM (0.20 MI) TO THE STATION ON THE RIGHT AT THE WEST END OF A
TS0340'FENCED AREA.
TS0340'THE MARK IS FASTENED TO THE TOP OF A COPPER CLAD ROD SET IN A 4-INCH
TS0340'PLASTIC PIPE WITH A SCREW CAP.  IT IS 4.7 M (15.4 FT) NORTH OF THE
TS0340'CENTER OF MAIN STREET, 1.8 M (5.9 FT) WEST OF A WOODEN FENCE, 0.9 M
TS0340'(3.0 FT) SOUTH-SOUTHWEST OF A WITNESS POST AND 0.8 M (2.6 FT)
TS0340'WEST-NORTHWEST OF A TELEPHONE LINE POLE.
TS0340
TS0340                          STATION RECOVERY (1991)
TS0340
TS0340'RECOVERED 1991
TS0340'RECOVERED IN GOOD CONDITION.
TS0340
TS0340                          STATION RECOVERY (1998)
TS0340
TS0340'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1998 (GAS)
TS0340'1.0 KM (0.60 MI) WESTERLY ALONG BAYVIEW AVENUE FROM THE POST OFFICE IN
TS0340'NEAH BAY, 4.7 M (15.4 FT) NORTH OF THE CENTERLINE OF MAIN STREET, 2.8
TS0340'M (9.2 FT) WEST OF THE SOUTHWEST CORNER OF A CHAIN-LINK FENCE
TS0340'ENCLOSING A MASS GRAVE AND A TOTEM POLE, 1.7 M (5.6 FT) SOUTHWEST OF A
TS0340'WITNESS POST, AND 0.3 M (1.0 FT) ABOVE THE LEVEL OF THE STREET.
TS0340'NOTE--THE MARK IS ON PROPERTY OWNED BY THE MAKAH INDIAN TRIBE,
TS0340'TELEPHONE NUMBER (360) 645-3201.  THE MONUMENT IS A STATE HARN
TS0340'STATION.  ACCESS TO THE DISK IS THROUGH A 4-INCH PVC CAP.
TS0340
TS0340                          STATION RECOVERY (1999)
TS0340
TS0340'RECOVERY NOTE BY NATIONAL OCEAN SERVICE 1999 (JGF)
TS0340'RECOVERED AS PREVIOUSLY DESCRIBED.

*** retrieval complete.
Elapsed Time = 00:00:01
```

APPENDIX D : GPS BASE STATION FIELD LOGS

Project No. & Name: ~~FP6088.010~~ 6088.012
Client Name: USACE GRW Eng
Location: ~~Colorado River at Yuma~~ Neah Bay, Wash

GROUND CONTROL LOG

SITE INFORMATION Site ID: T340 Site Name: TS0340

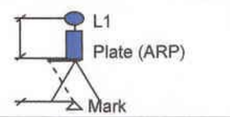
Site Type: ☑ Horiz Cntrl ☑ Vert Cntrl ☐ New ☐ Reoccupation

Receiver Type: Z-Max S/N: 8015 Antenna Type: Z-Max S/N: 2038

ANTENNA HEIGHT PARAMETERS Antenna Height is Vertical? ☐ Yes ☑ No

Mean Antenna Height		Ant. Radius (Plate radius)	Vert. Offset ARP to L1
Start	End		
1.737 m	1.738 m	m	m
in	in	in	in

Ant. Measuring Point Sketch



OBSERVATIONS Date: April 18/05 Observer Neil Kussat

	Time	Memory	Recording	SV #	PDOP	Record Interval
Start:	13:46 UTC 13:59 see Alert	95 (% Used)	☑ Yes ☐ No	08	1.7	1 secs
End:	20:22	86 (% Used)	☑ Yes ☐ No	08	1.8	

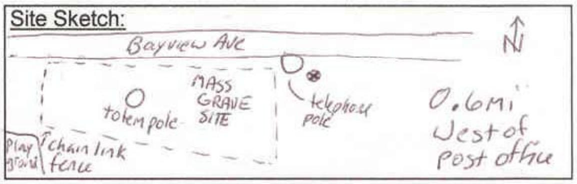
ALERTS at 16:59 the rec was shifted on the tripod base approx. 1.5 cm. (a flashlight was needed to locate the mark on the monument as it was located in a PVC pipe)

Office Checked By: ____________

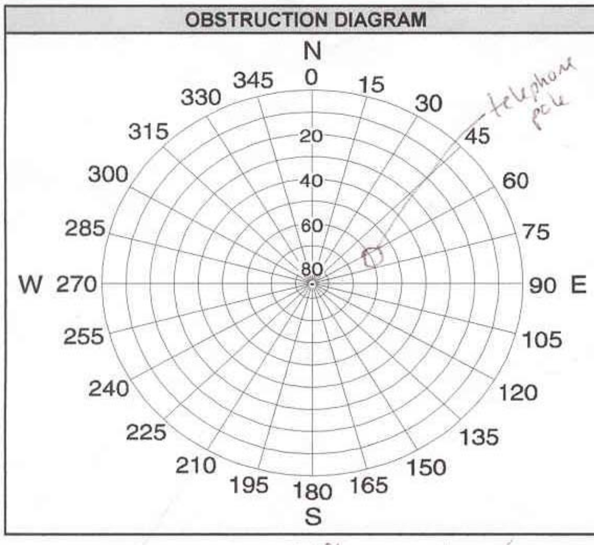
SITE SKETCH & NOTES

Start Antenna Height	End Antenna Height
1. 1.737	1. 1.738
2. 1.738	2. 1.738
3. 1.737	3. 1.737

Site Sketch:



OBSTRUCTION DIAGRAM



MONUMENT RUBBING / DESCRIPTION

Standard NOS Disk Stamped ... 309A 1982 Crimped to top of a galvanized steel rod recessed 23cm below ground encased in a 4-inch PVC pipe with screw cap.

Start 20:48 utc 86% Yes ✓ SV # 6/7 PDOP
End 02:00 79% Yes ✓ 6/7 1.9 1s

Project No. & Name: ~~FP6088.010~~ 6088.012
Client Name: ~~USACE~~ GRW Eng
Location: ~~Colorado River at Yuma~~ Neah Bay, Wash

GROUND CONTROL LOG

SITE INFORMATION Site ID: T342 Site Name: None

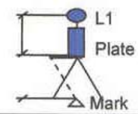
Site Type: ☐ Horiz Cntrl ☐ Vert Cntrl ☑ New ☐ Reoccupation

Receiver Type: Z-Max S/N: 9011 Antenna Type: Z-Max S/N: 2041

ANTENNA HEIGHT PARAMETERS Antenna Height is Vertical? ☐ Yes ☐ No

Mean Antenna Height Start	Mean Antenna Height End	Ant. Radius (Plate radius)	Vert. Offset ARP to L1
N/A m	m	m	m
in	in	in	in

Ant. Measuring Point Sketch



OBSERVATIONS Date: April 18/10 Observer: N. Kussat

	Time	Memory	Recording	SV #	PDOP	Record Interval
Start:	14:06	84 (% Used)	☐ Yes ☑ No	08	1.7	1 secs
End:	20:50	96 (% Used)	☐ Yes ☑ No	08	1.7	

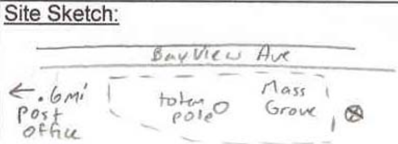
ALERTS

Office Checked By: ____________

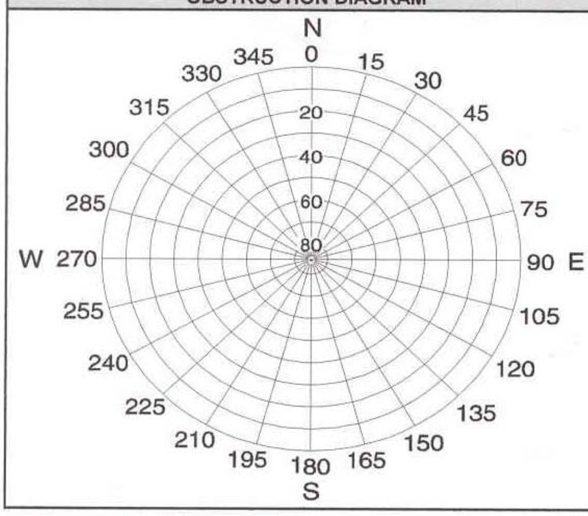
SITE SKETCH & NOTES

Start Antenna Height	End Antenna Height
1.	1.
2.	2.
3.	3.

Site Sketch:



OBSTRUCTION DIAGRAM



MONUMENT RUBBING / DESCRIPTION

Start 20:51 76% Yes✓ SV# 08 PDOP 1.7
End 02:02 68% 08 1.9

Project No. & Name: ~~FP6088.010~~ 6088.012
Client Name: USACE GRWEns
Location: ~~Colorado River at Yuma~~ Neah Bay, WA

GROUND CONTROL LOG

SITE INFORMATION Site ID: ~~Nea1~~ NEA1 Site Name:

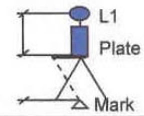
Site Type: ☐ Horiz Cntrl ☐ Vert Cntrl ☑ New ☐ Reoccupation

Receiver Type: Z-Max S/N: Antenna Type: Z-Max S/N:

ANTENNA HEIGHT PARAMETERS Antenna Height is Vertical? ☐ Yes ☐ No

Mean Antenna Height		Ant. Radius	Vert. Offset
Start	End	(Plate radius)	ARP to L1
1.119 m	1.119 m	m	0.327 m
in	in	in	in

Ant. Measuring Point Sketch



OBSERVATIONS Date: April 19/05 Observer: N. Kussat

	Time	Memory	Recording	SV #	PDOP	Record Interval
Start:	14:06 utc	92 (% Used)	☑ Yes ☑ No	~~8~~ 6	~~3~~ 2.4	1 secs
End:	01:00	77 (% Used)	☑ Yes ☑ No	8	1.8	

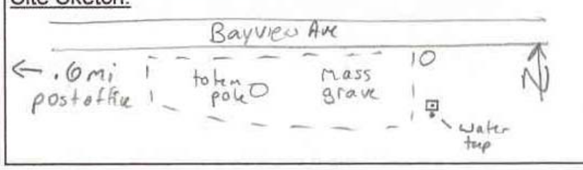
ALERTS

Office Checked By:

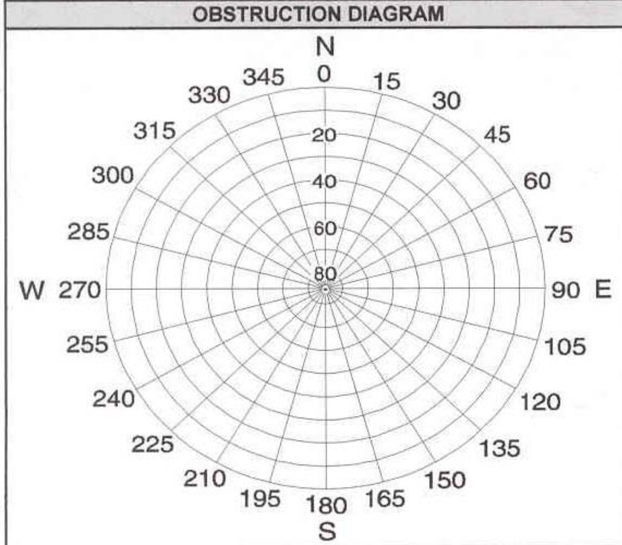
SITE SKETCH & NOTES

Start Antenna Height	End Antenna Height
1. 1.119	1. 1.119
2. 1.119	2. 1.119
3. 1.120	3. 1.119

Site Sketch:



OBSTRUCTION DIAGRAM



MONUMENT RUBBING / DESCRIPTION

nail in top of 4x4 post used to support water tap

Project No. & Name: ~~FP6088.010~~ 6088.012
Client Name: USACE GRW Eng
Location: ~~Colorado River at Yuma~~ Neah Bay, Wash

GROUND CONTROL LOG

SITE INFORMATION Site ID: T340 Site Name: T50340

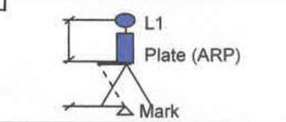
Site Type: ☑ Horiz Cntrl ☑ Vert Cntrl ☐ New ☐ Reoccupation

Receiver Type: Z-Max S/N: 9011 Antenna Type: Z-Max S/N: 2041

ANTENNA HEIGHT PARAMETERS Antenna Height is Vertical? ☐ Yes ☑ No

Mean Antenna Height		Ant. Radius (Plate radius)	Vert. Offset ARP to L1
Start	End		
1.687 m	1.687 m	m	0.327 m
in	in	in	in

Ant. Measuring Point Sketch



OBSERVATIONS Date: April 19, 2005 Observer N. Kussat

	Time	Memory	Recording	SV #	PDOP	Record Interval
Start:	13:53 utc	84 (% Used)	☐ Yes ☑ No	6	2.6	1 secs
End:	00:34	70 (% Used)	☐ Yes ☐ No	6	2.4	

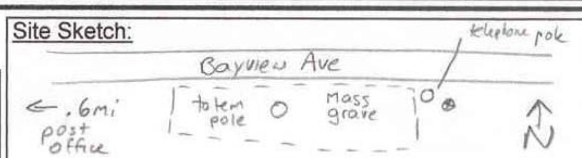
ALERTS

Office Checked By: ______

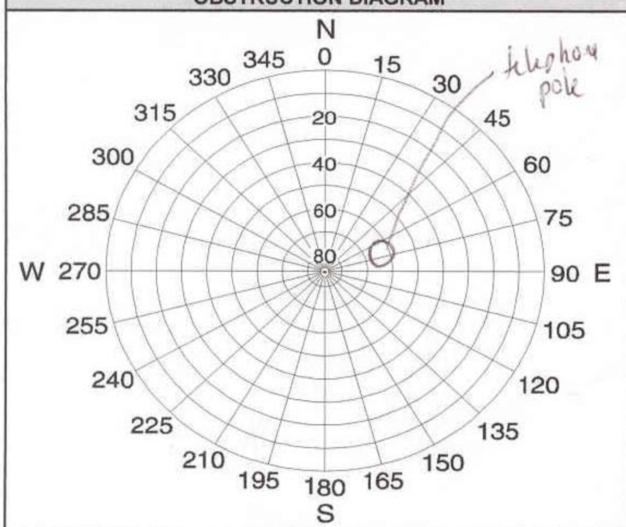
SITE SKETCH & NOTES

Start Antenna Height	End Antenna Height
1. 1.687	1. 1.687
2. 1.687	2. 1.687
3. 1.687	3. 1.687

Site Sketch:



OBSTRUCTION DIAGRAM



MONUMENT RUBBING / DESCRIPTION

Project No. & Name: ~~FP6088.010~~ 6088.012
Client Name: ~~USACE~~ GRW Eng
Location: ~~Colorado River at Yuma~~ NEAH BAY, WA

GROUND CONTROL LOG

SITE INFORMATION

Site ID: NEA1 Site Name: ______

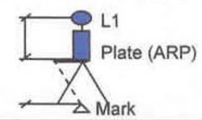
Site Type: ☐ Horiz Cntrl ☐ Vert Cntrl ☐ New ☐ Reoccupation

Receiver Type: Z-Max S/N: 8070 Antenna Type: Z-Max S/N: 2035

ANTENNA HEIGHT PARAMETERS

Antenna Height is Vertical? ☐ Yes ☑ No

Mean Antenna Height		Ant. Radius	Vert. Offset	Ant. Measuring Point Sketch
Start	End	(Plate radius)	ARP to L1	
1.269 m	m	m	0.327 m	
in	in	in	in	



OBSERVATIONS

Date: April 20/05 Observer: N. Kussat

	Time	Memory	Recording	SV #	PDOP	Record Interval
Start:	15:14 utc	99 (% Used)	☑ Yes ☐ No	07	2.2	1 secs
End:	00.00	87 (% Used)	☑ Yes ☐ No	07	2.2	

ALERTS

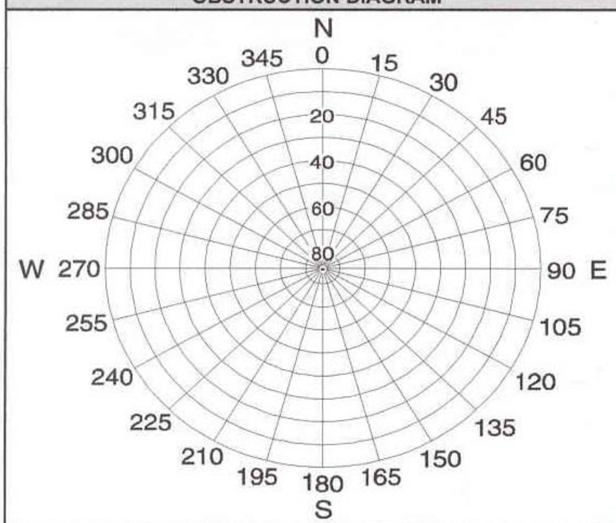
Office Checked By: ______

SITE SKETCH & NOTES

Start Antenna Height	End Antenna Height
1. 1.269	1.
2. 1.269	2.
3. 1.270	3.

Site Sketch:

OBSTRUCTION DIAGRAM



MONUMENT RUBBING / DESCRIPTION

Standard NOS

Project No. & Name: ~~FP6088.010~~ 6088.012
Client Name: ~~USACE~~ GRW Eng
Location: ~~Colorado River at Yuma~~ Neah Bay, WA

GROUND CONTROL LOG

SITE INFORMATION Site ID: T340 Site Name: TS0340

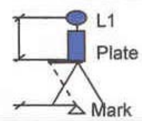
Site Type: ☐ Horiz Cntrl ☐ Vert Cntrl ☐ New ☐ Reoccupation

Receiver Type: Z-Max S/N: 9011 Antenna Type: Z-Max S/N: 2041

ANTENNA HEIGHT PARAMETERS Antenna Height is Vertical? ☐ Yes ☑ No

Mean Antenna Height		Ant. Radius	Vert. Offset
Start	End	(Plate radius)	ARP to L1
1.766 m	m	m	.327 m
in	in	in	in

Ant. Measuring Point Sketch



OBSERVATIONS Date: April 20/05 Observer N. Kussat

	Time	Memory	Recording	SV #	PDOP	Record Interval
Start:	15:04 utc	99 (% Used)	☑ Yes ☐ No	7	2.0	1 secs
End:	23:59	87 (% Used)	☑ Yes ☐ No	7	2.0	

ALERTS

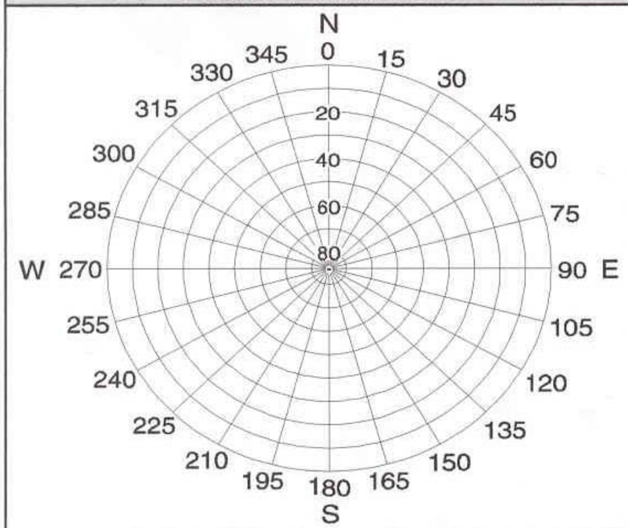
Office Checked By: ______

SITE SKETCH & NOTES

Start Antenna Height	End Antenna Height
1. 1.767	1.
2. 1.766	2.
3. 1.766	3.

Site Sketch:

OBSTRUCTION DIAGRAM



MONUMENT RUBBING / DESCRIPTION

Standard NOS Disk
Stamped --- 309A 1982 ---
Crimped to the top of a galvanized steel rod recessed 23 cm below ground encased in a 4-inch PVC pipe with screw cap

Project No. & Name: 6088.012
Client Name: GRW Eng
Location: Neah Bay

GROUND CONTROL BASE STATION LOG

SITE INFORMATION Site ID: NEA1 Site Name: —

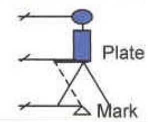
Site Type: ☐ Horiz Cntrl ☐ Vert Cntrl ☐ New ☑ Reoccupation

Receiver Type: Z-Max S/N: 8015 Antenna Type: Z-Max S/N: 2038

ANTENNA HEIGHT PARAMETERS Phase Offset Included? ☐ Yes ☐ No

Mean Antenna Height-Slant		Ant. Radius	Vert. Offset
Start	End		
1.163 m	m	m	m
in	in	in	in

Ant. Measuring Point Sketch



OBSERVATIONS Date: April 22/05 Observer:

	Time	Memory	Recording	SV #	PDOP	Record Interval
Start:	15:45 utc	99 (% Used)	☑ Yes ☐ No	07	2.2	1 secs
End:	02:03	87 (% Used)	☑ Yes ☐ No	00	6.2	

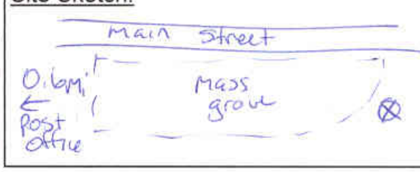
ALERTS

Office Checked By:

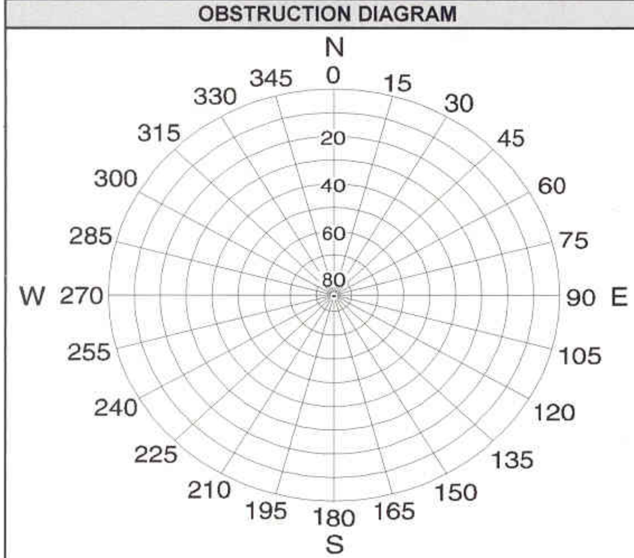
SITE SKETCH & NOTES

Start Antenna Height	End Antenna Height
1. 1.163	1. 1.162
2. 1.162	2. 1.163
3. 1.163	3. 1.163

Site Sketch:



OBSTRUCTION DIAGRAM



MONUMENT RUBBING / DESCRIPTION

nail in top of 4x4 post supporting water tap

Project No. & Name: 6088.012
Client Name: GRW Eng.
Location: Neah Bay

GROUND CONTROL BASE STATION LOG

SITE INFORMATION Site ID: T340 Site Name: TS0340

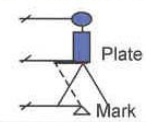
Site Type: ☑ Horiz Cntrl ☑ Vert Cntrl ☐ New ☐ Reoccupation

Receiver Type: Z-Max S/N: 9011 Antenna Type: Z-Max S/N: 2041

ANTENNA HEIGHT PARAMETERS Phase Offset Included? ☐ Yes ☑ No

Mean Antenna Height-Slant		Ant. Radius	Vert. Offset
Start	End		
1.768 m	1.768 m	m	m
in	in	in	in

Ant. Measuring Point Sketch



OBSERVATIONS Date: April 22/05 Observer N. Kossat

	Time	Memory	Recording	SV #	PDOP	Record Interval
Start:	15:36 utc	99 (% Used)	☑ Yes ☐ No	06	2.7	1 secs
End:	01:56	85 (% Used)	☑ Yes ☐ No	08	1.8	

ALERTS

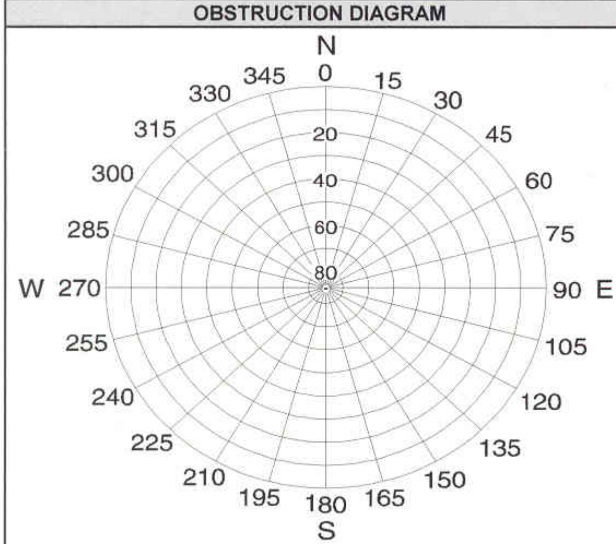
Office Checked By:

SITE SKETCH & NOTES

Start Antenna Height	End Antenna Height
1. 1.768	1. 1.768
2. 1.768	2. 1.768
3. 1.768	3. 1.768

Site Sketch:

OBSTRUCTION DIAGRAM



MONUMENT RUBBING / DESCRIPTION

Project No. & Name: 6088.012
Client Name: GRU Eng
Location: Neah Bay, WA

GROUND CONTROL BASE STATION LOG

SITE INFORMATION Site ID: NEA1 Site Name:

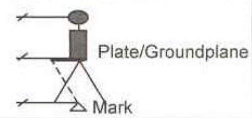
Site Type: ☐ Horiz Cntrl ☐ Vert Cntrl ☐ New ☑ Reoccupation

Receiver Type: S/N: 8015 Antenna Type: S/N: 2038

ANTENNA HEIGHT PARAMETERS Phase Offset Included? ☐ Yes ☑ No

Mean Antenna Height-Slant		Ant/Plate Radius	Vert. Offset
Start	End		
1.094 m	1.093 m	m	0.327 m
in	in	in	in

Ant. Measuring Point Sketch



OBSERVATIONS Date: April 23/05 Observer: N. Kussat

	Time	Memory	Recording	SV #	PDOP	Record Interval
Start:	15:12 utc	99 (% Used)	☑ Yes ☐ No	01	2.6	1 secs
End:	22:21	92 (% Used)	☑ Yes ☐ No	00	2.3/2.1	

ALERTS

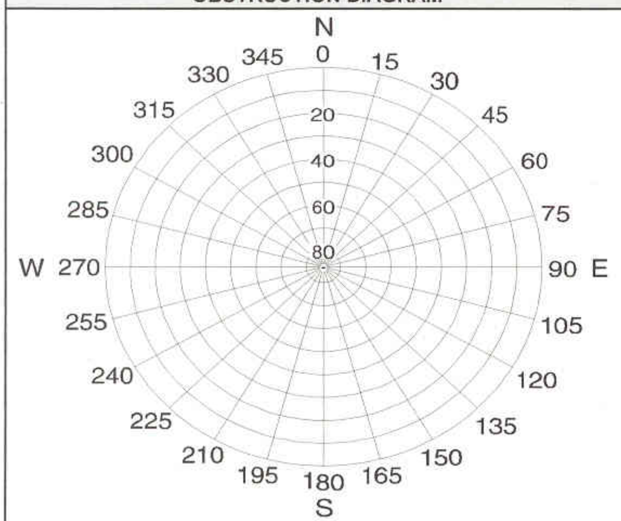
Office Checked By:

SITE SKETCH & NOTES

Start Antenna Height	End Antenna Height
1. 1.094 m	1. 1.094
2. 1.094	2. 1.093
3. 1.094	3. 1.093

Site Sketch:

OBSTRUCTION DIAGRAM



MONUMENT RUBBING / DESCRIPTION

Project No. & Name: 6088.012
Client Name: GRW Eng.
Location: Neah Bay

GROUND CONTROL BASE STATION LOG

SITE INFORMATION Site ID: T340 Site Name: TS0340

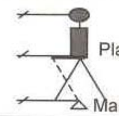
Site Type: ☑ Horiz Cntrl ☑ Vert Cntrl ☐ New ☐ Reoccupation

Receiver Type: ______ S/N: 9011 Antenna Type: ______ S/N: 2041

ANTENNA HEIGHT PARAMETERS Phase Offset Included? ☐ Yes ☑ No

Mean Antenna Height-Slant		Ant/Plate Radius	Vert. Offset
Start	End		
1.753 m	1.753 m	m	.327 m
in	in	in	in

Ant. Measuring Point Sketch



OBSERVATIONS Date: April 23/05 Observer N. Kussat

	Time	Memory	Recording	SV #	PDOP	Record Interval
Start:	15:02 utc	85 (% Used)	☑ Yes ☐ No	07	2.2	1 secs
End:	22:8417	75 (% Used)	☑ Yes ☐ No	09	2.1	

ALERTS

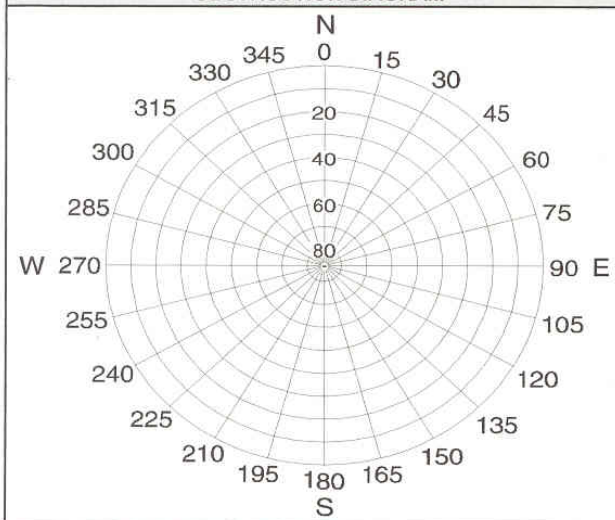
Office Checked By: ______

SITE SKETCH & NOTES

Site Sketch:

Start Antenna Height	End Antenna Height
1. 1.753	1. 1.753
2. 1.7525	2. 1.753
3. 1.753	3. 1.753

OBSTRUCTION DIAGRAM



MONUMENT RUBBING / DESCRIPTION

Project No. & Name: 6088.012
Client Name: GRW Eng
Location: Nean Bay, WA

GROUND CONTROL BASE STATION LOG

SITE INFORMATION Site ID: NEA1 Site Name:

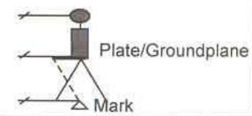
Site Type: ☐ Horiz Cntrl ☐ Vert Cntrl ☐ New ☑ Reoccupation

Receiver Type: S/N: 8015 Antenna Type: ~~22~~ S/N: 2038

ANTENNA HEIGHT PARAMETERS Phase Offset Included? ☐ Yes ☑ No

Mean Antenna Height-Slant		Ant/Plate Radius	Vert. Offset
Start	End		
1.199 m	1.199 m	m	0.327 m
in	in	in	in

Ant. Measuring Point Sketch



OBSERVATIONS Date: April 24/05 Observer N. Kossat

	Time	Memory	Recording	SV #	PDOP	Record Interval
Start:	17:30 utc	99 (% Used)	☑ Yes ☐ No	00	2.3	1 secs
End:	22:57	93 (% Used)	☑ Yes ☐ No	00	4.7	

ALERTS

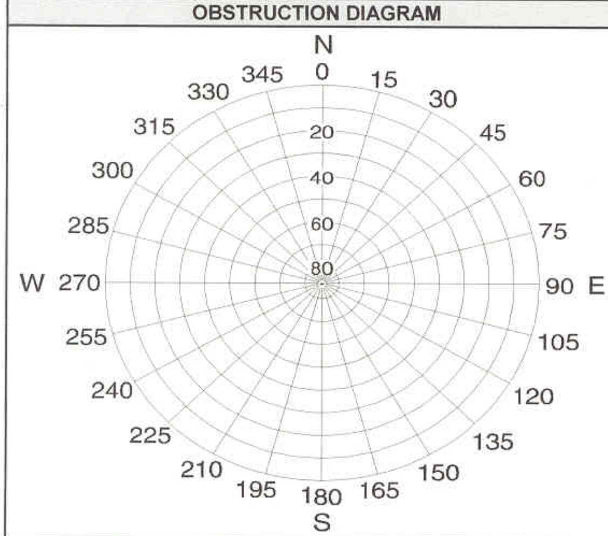
Office Checked By:

SITE SKETCH & NOTES

Start Antenna Height	End Antenna Height
1. 1.199	1. 1.199
2. 1.199	2. 1.199
3. 1.199	3. 1.199

Site Sketch:

OBSTRUCTION DIAGRAM



MONUMENT RUBBING / DESCRIPTION

Project No. & Name: 6088.012
Client Name: GRW Eng
Location: Neah Bay

GROUND CONTROL BASE STATION LOG

SITE INFORMATION Site ID: T340 Site Name: TS0340

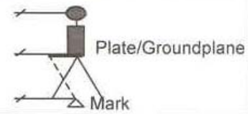
Site Type: ☑ Horiz Cntrl ☑ Vert Cntrl ☐ New ☐ Reoccupation

Receiver Type: ______ S/N: 9011 Antenna Type: ______ S/N: 2041

ANTENNA HEIGHT PARAMETERS Phase Offset Included? ☐ Yes ☑ No

Mean Antenna Height-Slant		Ant/Plate Radius	Vert. Offset
Start	End		~~0~~
1.719 m	1.719 m	m	0.327 m
in	in	in	in

Ant. Measuring Point Sketch



OBSERVATIONS Date: April 24/05 Observer: N. Kussat

	Time	Memory	Recording	SV #	PDOP	Record Interval
Start:	17:17 UTC	99 (% Used)	☑ Yes ☐ No	08	1.7	1 secs
End:	22:52	91 (% Used)	☑ Yes ☐ No	10	1.6	

ALERTS

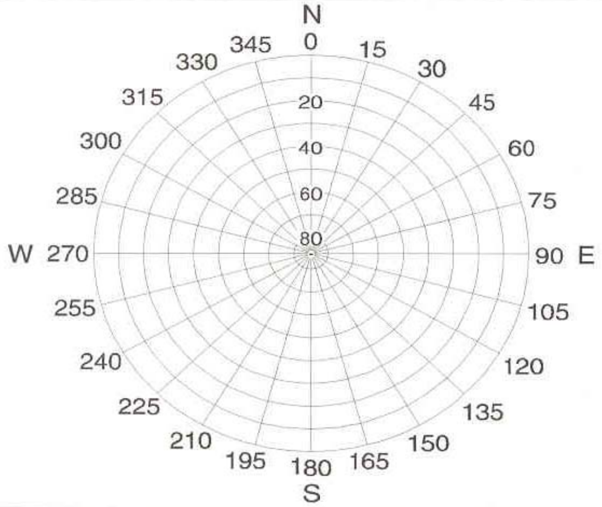
Office Checked By: ______

SITE SKETCH & NOTES

Start Antenna Height	End Antenna Height
1. 1.719	1. 1.719
2. 1.719	2. 1.719
3. 1.719	3. 1.719

Site Sketch:

OBSTRUCTION DIAGRAM

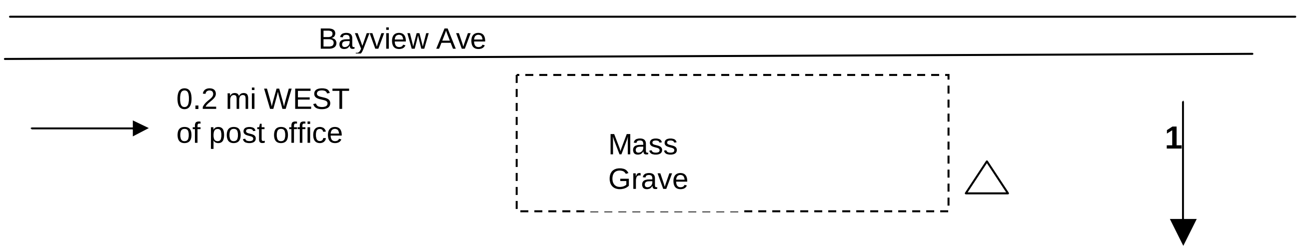


MONUMENT RUBBING / DESCRIPTION

APPENDIX E : STATION DECSRIPTIONS (NEA1)

COUNTRY	AREA/REGION	STATION NAME	
USA	Neah Bay, WA	NEA1	
National System NGS		**Station No. in System**	
	Co-ordinates System 1	**Co-ordinates System 2**	**Datum Shift System 1 to System 2**
Spheroid	GRS80	ITRF2000	
Datum	NAD 83 (2002)	ITRF2000	
Latitude	48º 22’ 0.93986”		
Longitude	124º 37’ 15.47111”		
Ellipsoid Ht.	-15.115 m		
Easting	379945.141 m		Scale Factor
Northing	5358353.481 m		
Elevation	5.732		
Elev. Datum	NAVD88 (GEOID99)		
Projection	UTM 10 N m		
False Easting	500000 m		
False Northing	0 m		
C. Meridian	123º 00’ 00”		
Date of Survey	04/18/05	**Lastest revision**	04/18/05
Source of Data		Static GPS survey	
Description of Station Mark		Nail in 4x4 post	

Site Plan with Witness Marks:

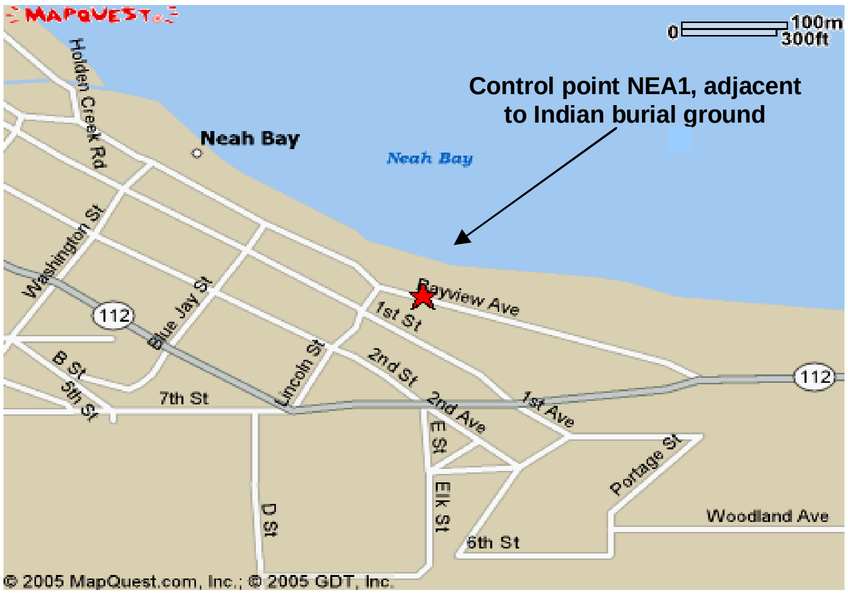


STATION NAME	NEA1

LOGISTIC INFORMATION			
Main Supply	Neah Bay	**How Far?** N/a	**What Supply?** Everything
Diesel Fuel/Petrol	Yes	**Where From?**	Neah Bay
Water (potable)	Yes	**If No-Where?**	N/a
Watchmen	Yes	**Security Problems?**	Public area, on Indian reservation
Local Contact	Makah Indian Tribe (306) 645-3201		
Seasonal Status Local Roads	Good year-round		
Travel Time to Accom	2 hrs from Port Angeles	**Nearest Accom**	Neah Bay
Mast Required?	No	**If Yes, How High?**	N/a
Official Docs req'd	No		
4WD Vehicle	No	**Vehicles From?**	Airport rentals
Site Owner/Tenant	N/a		
Other Information			
Compiled By	N. Kussat	**Date**	April 18, 2005

STATION NAME	NEA1	USGS QUAD	NEAH BAY

ACCESS MAP:



DESCRIPTION OF ACCESS:

The station is located in the western section of Neah Bay, at an Indian burial area. To reach the station from the post office and store in Neah Bay, travel 0.2 miles west on Bayview Ave. to a fenced in grass area on the right(north) containing a totem pole. The station is at the North-west corner of the fence, adjacent to a telephone pole. The point is a nail in a 4x4 stud supporting a water faucet.

APPENDIX F : AIRCRAFT SPECIFICATIONS

AIRPLANE	BEECHCRAFT KING AIR
Official Number	N80Y
Owner	Dynamic Aviation
Wing Span	47 ft 10.5 in
Length	35 ft 6 in
Gross Weight	9,650 lbs
Typical Empty Weight	5,150 lbs
Survey Mode Duration	~4-5 hours
Engine	PT6A-20 (Jet)

APPENDIX G : SHOALS-1000T EQUIPMENT SPECIFICATIONS

SHOALS Specifications

Hydrographic Mode

Guidelines only. Actual specifications depend on SHOALS product and operating environment.
All specifications subject to change without notice.

Measurement rate	1000 Hz
Operating altitude	200-400 m
Depth measurement accuracy	IHO Order 1 (25 cm, 1 σ)
Depth penetration	0.1-50 m
Maximum depth	kD = 3.0
Scan angle	20° forward arc
Sounding density	2x2, 3x3, 4x4, 5x5 m
Swath width	Variable, up to 0.58 x altitude
Scan frequency	Variable, depends on scan pattern
Horizontal accuracy	IHO Order 1 (2.5 m, 1 σ)
Laser classification	Class IV laser product (US FDA CFR 21)
Eyesafe altitude	150 m
Power requirements	100 A @ 28 VDC
Operating temperature	5-40° C
Aircraft speed	125-175 knots

Topographic Mode

Measurement rate	1000 Hz
Operating altitude	300-700 m
Horizontal accuracy	DGPS - 2.5 m, 1 σ; KGPS - 1/200 x altitude
Vertical accuracy	25 cm, 1 σ

Equipment

Sensor dimensions	50 x 50 x 60 cm
Sensor weight	65 kg
Control rack dimensions	60 x 60 x 70 cm each
Control rack weight	65 kg each

POS AV™

position & orientation system **airborne vehicles**

Aided Intertial Solutions for Airborne Applications

POS AV is a fully integrated position and orientation system designed specifically for airborne applications. The system integrates precision GPS with inertial technology to provide real-time and post-processed (POSPac) measurements of the position, roll, pitch and heading of airborne sensors. Engineered for use with aerial cameras, scanning lasers, imaging scanners and synthetic aperture radar (SAR) – POS AV enables the rapid creation of digital terrain models (DTMs), orthophotos and digital maps.

A Revolution in Airborne Surveying and Mapping

Over the last few years there has been a large increase in the number of digital sensors used for airborne data collection. Scanning lasers and line scanners, for example, are now widely used for aerial surveying and mapping. POS AV has been the enabling technology behind this growth, because it allows you to do what was never before possible: quickly and accurately motion compensate and geocode airborne sensor data. With POS AV, data can be geometrically corrected and then geographically encoded and mosaicked to produce precise DTMs and orthophotos.

POS AV Increases Your Productivity

By directly measuring the sensor's position and attitude with high accuracy and at high data rates, POS AV greatly reduces the need for labour-intensive ground control and elaborate post-processing. This allows you to carry out aerial surveys quickly and cost-effectively, with turnaround times as short as 24 hours for:

- mapping of uniformly textured areas (water, deserts, forests)
- stripline mapping
- spot mapping
- coastal surveying (highway, pipeline and powerline)
- flood plain mapping

Image courtesy of Northwest Geomatics

POS AV is...

Accurate with high-bandwidth

- 0.005 pitch/roll, 0.008 heading (POS AV 510 – post-processed)
- 5-10 cm sensor positioning (post-processed)
- 200 Hz data rates
- Real-time data with < 3 msec latency
- Precise time-alignment of POS data with airborne sensor

Modular

- Compact, lightweight IMU (Inertial Measurement Unit) mounts easily on any airborne sensor
- Powerful PCS (POS Computer System) contains:
  - the core POS processor
  - PC drive
  - removable PC-card disk
  - embedded, low-noise, dual-frequency GPS receiver

Flexible

- Real-time and post-processed operation
- Data logging via Ethernet and/or removable PC-card disk for post-processing on PC laptop
- Multiple, reconfigurable interfaces for:
  - differential GPS
  - time alignment of airborne sensors
  - flight management systems
  - stabilized platforms

Convenient

- System can be installed in only a few hours
- In-air alignment capability
- Menu-driven controller and display software run under Windows on your PC laptop
- Autonomous, stand-alone operation

Reliable

- Rugged PC-based computer designed specifically for airborne applications
- Fully shock-and vibration-tested
- Temperature-and altitude-tested

Fully Supported

- Full installation, training and customer support by highly qualified field specialists
- Developed by a solid company with years of experience in aided inertial technology for airborne applications

direct georeferencing of aerial sensors

POS AV Models with POSPac™

Applanix has developed four POS AV models that provide accuracy levels suitable for the full range of airborne sensors. Each model is sold with our post-processing software POSPac, which optimally blends integer carrier-phase GPS data with inertial data, significantly increasing your productivity.

POS AV™ 210:

Roll/pitch: 0.04° RMS/ 2 arcmin RMS (post-processed)
Heading: 0.08° RMS/ 5 arcmin RMS (post-processed)
Sensor position: 5-10cm RMS

POS AV™ 310:

Roll/pitch: 0.013° RMS/ 50 arcsec RMS (post-processed)
Heading: 0.035° RMS/ 2 arcmin RMS (post-processed)
Sensor position: 5-10 cm RMS

POS AV™ 410:

Roll/pitch: 0.008° RMS/ 30 arcsec RMS (post-processed)
Heading: 0.015° RMS/ 1 arcmin RMS (post-processed)
Sensor position: 5-10 cm RMS

POS AV™ 510:

Roll/pitch: 0.005° RMS/ 20 arcsec RMS (post-processed)
Heading: 0.008° RMS/ 30 arcsec RMS (post-processed)
Sensor position: 5-10 cm RMS

DG Option (Direct Georeferencing) – POSEO™:

Each POS AV system can be used to automatically generate plotter-ready exterior orientation (EO) data for frame cameras simply by adding the software module POSEO to the post-processing software suite.

Inertial/GPS Integration

All POS systems blend linear acceleration and angular rate measurements provided by the inertial sensors, with position and velocity measurements of GPS to compute a highly accurate solution for all motion variables. POS retains the best capabilities of both inertial and GPS, with performance characteristics that are better than those of either GPS or inertial alone.

Using GPS data to calibrate inertial sensors on-line, POS maintains the dynamic fidelity of the inertial solution, yet removes any long-term, systematic drifts from the inertially derived position and orientation. The calibrated inertial solution allows POS to maintain accuracy while navigating through GPS outages.

Image courtesy of EarthData

The image above (a colorized infrared orthophoto draped over a LIDAR Digital Elevation Model) was obtained using EarthData Technologies' LIDAR system and Applanix' POS AV at 2140m AMT. EarthData flew this LIDAR for the Grand Canyon Monitoring and Research Center.

POS AV System Inertial Measurement Unit (IMU), POS Computer System with embedded GPS reciever, and antenna

OmniSTAR® 3100LM DGPS Receiver Module

The Global Positioning System

The OmniSTAR 3100LM combines the reception of high performance differential corrections with a compact, light weight and robust design, ideally suited for backpack or On-the-Belt applications.

The OmniSTAR 3100LM is a fully functional differential corrections receiver, designed to be used with an external (handheld) GPS receiver. Its design is based on proven OmniSTAR OEM technology, currently utilised in many OmniSTAR compatible applications.

Features

- Compact, light weight portable receiver
- Robust design with high quality components
- Minimal power requirements
- Real time status indicators
- Output RTCM 104
- Remote access facility (via satellite link)
- Compatible with most common antenna systems
- Internal antenna splitter
- Designed for portable use; all connectors and indicators located on one side of the receiver
- Free 24 hour technical support
- Quality control statistics available to the user

OmniSTAR DGPS services

OmniSTAR transmits differential GPS data world wide using a global network of reference stations to measure errors in the GPS system and generate corrections

This reference data is gathered at a network control centre where it is checked for integrity and reliability and is up-linked to a series of geo-stationary satellites, which distribute the data around the world. The OmniSTAR service is available by subscription.

VBS - Virtual Base Station

OmniSTAR's Virtual Base Station (VBS) Service is a unique world-wide high precision service with sub-meter accuracy throughout the coverage area (subject to the quality of the GPS receiver used).
The high level of accuracy is made possible by processing all available reference data into a set of corrections, optimised for the users actual location. This provides the end-user with a consistent and high accuracy over a large area.

The features of OmniSTAR's differential corrections service

- OmniSTAR differential corrections are highly reliable (not dependent on any single reference station)
- No position jumps due to switching from one reference station to another
- All reference stations have dual data connections to their network control centre
- Multiple up-links are used (primary and backup)
- The European continent is covered by several satellite services

OmniSTAR Global Coverage

OmniSTAR corrections can be utilised around the world.

We operate a world-wide network of reference stations, controlled by two Network Control Centres. These Network Control Centres also provide free of charge, 24 hour technical support to OmniSTAR users, should they require it.

OmniSTAR Applications

- Airborne geophysics
- Mapping & boundary marking
- Precision farming
- Aerial farming applications
- Search & rescue guidance
- Vehicle location & positioning
- Navigation
- Environmental monitoring
- GIS data acquisition
- Defence application
- Asset management
- Aviation photogrammetry
- Surveying

MBX-3

2 Channel Automatic Differential Beacon Receiver

Standalone Radiobeacon Receiver

FEATURES

- Dual independent channels for superior automatic beacon tracking
- State-of-the-art digital architecture enhances beacon reception
- Fast acquisition times ensure you are up and running quickly
- 2-line by 16-character LCD display provides more information simultaneously
- Global beacon table listing gives you quick access to beacons by name
- Low power consumption gives extended battery life for portable applications
- Automatic and manual tune modes provide operational versatility
- Optional internal splitter and GPS signal output port for use with combination GPS/beacon antennas
- Firmware upgrades are easily loaded into the receiver through the serial port
- Wide selection of antennas available

Advanced Beacon Receiver Technology

The CSI MBX-3 beacon receiver employs CSI's third generation of digital receiver technology to receive free DGPS signals broadcast by the networks of 300 kHz radiobeacons deployed worldwide.

Using these signals, the MBX-3 beacon receiver outputs differential correction data in the industry standard RTCM SC-104 format accepted by differential-ready GPS receivers.

The advanced digital signal processing techniques of the MBX-3 allow for reliable extraction of DGPS data from the beacon broadcasts, even in noisy environments.

Ease of Operation

The MBX-3 incorporates a large 2-line by 16-character display and 3-switch keypad. The intuitive menu system provides access to receiver status information and operating parameters.

You may configure the MBX-3 beacon receiver for either automatic or manual tune operation using the convenient menu system.

A new global beacon table within the receiver menu system allows selection of beacons by name.

Automatic Operation

In automatic mode, the two channels of the beacon receiver cooperatively construct and maintain a table of radiobeacons available in your area. The receiver's primary channel automatically locks to the station providing the highest quality signal. This ensures that the MBX-3 is always locked to the best beacon in the area.

Antennas

The MBX-3 receiver may use any of a variety of antennas offered by CSI. Options include an E-field Whip antenna, two varieties of H-field beacon Loop antennas, and a combination GPS/beacon antenna.

All CSI antennas incorporate band-pass filtering and integral preamplifiers. The MBX-3 receiver provides power to these active antennas.

H-field beacon Loop antennas do not require a counterpoise ground connection and are ideal for portable applications. They are also less susceptible than a conventional whip antenna to predominate E-field noise, including precipitation static.

Hassle-Free Upgrading

The MBX-3 supports firmware upgrades as improvements to firmware or changes to the global beacon table are made. These upgrades are easily loaded into the receiver through the serial port using a PC computer.

Configuration Software

CSI offers custom Windows 95® software for beacon receiver configuration, monitoring receiver performance, and decoding RTCM data. A terminal interface and data logging capability are also included.

Warranty

CSI is committed to supporting its products and offers a one-year warranty on parts and labor.

Contact us to discover why the MBX-3 is the right choice for your application.

MBX-3 – *2 Channel Automatic Differential Beacon Receiver*

Receiver Specifications

Channels:	2 independent channels
Frequency Range:	283.5 to 325.0 kHz
Channel Spacing:	500 Hz
MSK Bit Rates:	50, 100, and 200 bps
Cold Start Time:	< 1 minute
Warm Start Time:	< 2 seconds
Demodulation:	Minimum shift keying
Sensitivity:	2.5 µV/m for 10 dB SNR
Dynamic Range:	100 dB
Frequency Offset:	± 5 Hz
Adjacent Channel Rejection:	60 dB
Correction Output Protocol:	RTCM SC-104
Input/Status Protocol:	NMEA 0183

Communications

Interface Level:	RS-232C or RS-422
Baud Rates:	2400, 4800, 9600

Environmental Specifications

Operating Temperature:	-30°C to +70°C
Storage Temperature:	-40°C to +80°C
Humidity:	95% non-condensing
EMC:	EN 60945 EN 50081-1 EN 50082-1 FCC: Part 15, sub-part J, class A digital device

Power Specifications

Input Voltage:	9 - 40 VDC
Nominal Power:	2.5 W
Nominal Current:	210 mA
Antenna Voltage Output:	10 VDC (5 VDC optional)

Mechanical Specifications

Dimensions:	150 mm L x 125 mm W x 51 mm H (5.9" L x 4.9" W x 2.0" H)
Weight:	0.64 kg (1.4 lb)
Display:	2-line by 16-character LCD
Keypad:	3-key switch membrane
Power Connector:	2-pin circular locking
Data Connector:	DB9-S
Antenna Connector:	BNC-S
Optional GPS Output Port:	TNC-S

Operating Modes

MBX-3 Mode (Default):	RTCM SC-104 correction and NMEA status message output (Default Mode)
MBX-E Mode:	RTCM SC-104 correction and NMEA status message output and GPS NMEA message input for position and satellite status display.

NMEA 0183 I/O

- Receiver Automatic and Manual tune command
- Frequency and data rate query
- Receiver performance and operating status queries
- Automatic search almanac queries (proprietary)
- Baud rate selection command (proprietary)
- Receiver tune command
- Force cold start command (proprietary)
- Software upgrade command (proprietary)
- Configuration up-load command (proprietary)

Accessories

Antenna:	Various
Power Cables:	Various
Antenna Cables:	Various
Data Cables:	Various
CSI Beacon Command Center:	MS Windows 95® beacon control software

Pin-Out, RS-232C

DB9 Pin #	Description
2	TXD, RTCM SC-104 / status output
3	RXD, configuration input
5	Signal return

Pin-Out, RS-422

DB9 Pin #	Description
1	TXD +, RTCM SC-104 / status output
2	TXD -, RTCM SC-104 / status output
4	RXD -, configuration input
5	Signal return
7	RXD +, configuration input

CSI Authorized Dealer

Communication Systems International, Inc.
1200 – 58th Avenue S.E., Calgary, AB, Canada, T2H 2C9
Phone: (403) 259-3311 Fax: (403) 259-8866
Web: www.csi-dgps.com e-mail: info@csi-dgps.com

DT4000

1-CCD Camera
1600(H) x 1200(V) Pixels
Color or Monochrome

HIGH RESOLUTION DIGITAL CAMERA

High Resolution 1600 x 1200 Progressive Scan Digital Camera in RGB AccuColor and Monochrome Configurations

DuncanTech's *DT4000 Digital Camera* provides the crisp, clear images that only all-digital processing can provide. The camera uses the latest in advanced large-fomat progressive scan CCD sensors to maximize quantum efficiency and sensitivity. Both color and monochrome configurations are available. The 11.8 x 8.9 mm sensor has 3.5 times the sensing area of a 1/2" sensor and twice the sensing area of a 2/3" sensor delivering a significant increase in sensitivity. Interline transfer technology provides electronic shuttering.

In color configurations, the *DT4000* employs DuncanTech's proprietary *AccuColor* algorithm to deliver crisp, clear color images directly from the camera - no need for post-processing. *AccuColor* improves resolution and minimizes color aliasing, rivaling the image quality of many 3-CCD cameras.

The camera's advanced digital processing offers a number of features to maximize usability and image quality. Auto-exposure control and semi-automatic white-balance optimize performance. Digital Crosshairs simplify camera targeting. Multiple triggering modes provide accurate acquisition timing. Programmable control of image plane multiplexing enables display and output of the composite image, any single color plane, the raw pixel data, or any combination of these.

A Camera Link data interface supports the latest generation of digital framegrabbers. LVDS and RS-422 parallel options are also available. The *DirectView* analog video option adds the capability to simultaneously preview or record the image in NTSC, PAL, or progressive scan RGB format at resolutions up to 1280x1024.

FEATURES

- 1600(H) x 1200(V) CCD imaging sensor (11.8 mm x 8.9 mm)
- Available in RGB color or monochrome
- Frame rate of 10 fps
- *AccuColor* in-camera, real-time color interpolation
- 7.4 micron square pixels for accurate image metrics
- Display composite RGB or individual color plane images as monochrome images
- Digital Image Output - Camera Link, LVDS, or RS-422
- Auto-exposure control and semi-auto white balance for ease of use
- External trigger input with three operating modes
- Digital cross-hairs for easy camera targeting
- Analog gain control for each color maximizes dynamic range
- Digital gain and exposure control
- RS-232 interface for configuration and control
- Compact, rugged package
- Uses standard Nikon Bayonet Mount and High Resolution Graphics Lens
- Optional *DirectView* video preview with built-in zoom

DuncanTech
A SPECTRUM OF SOLUTIONS

4000-1-12/17/01

SPECIFICATIONS: DT4000

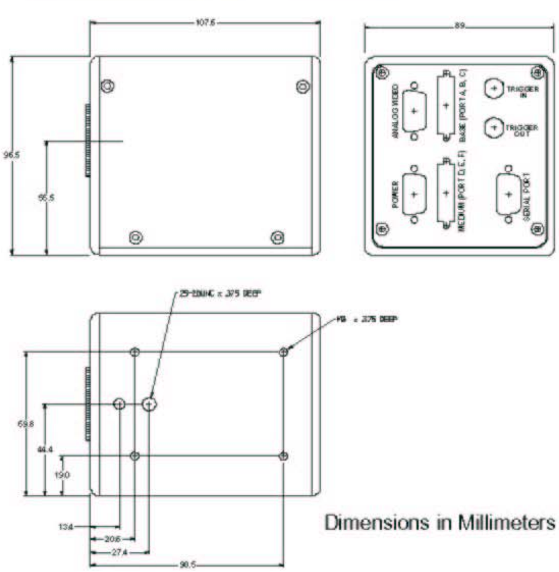
Image Device:	1 - Inch Interline Transfer CCD
Picture Elements:	1600(H) x 1200(V)
Pixel Size:	7.4 x 7.4 micron
Pixel clock rate:	22 MHz max
Sensing Area:	11.8 x 8.9 mm
Frame Rate:	10 frames per second - Standard. 5 frames per second - Low Noise Mode
Digital Image Output:	8 bits x 4 taps or 10 bits x 3 taps, Camera Link, EIA-644 (LVDS) or RS422
Signal/Noise:	54 dB - Standard. 60 dB - Low Noise Mode.
Sensitivity:	.5 lux - color; .2 lux - monochrome
Lens Mount:	C-Mount and Nikon Bayonet Mount
Electronic Shutter:	Range: 1/10,000 - 1/10 sec - Standard. 1/6,000 - 1/5 sec - Low Noise Mode.
Gain Selection:	Range: 0-36 dB. Controlled via RS-232 input.
External Trigger Input	Edge or level, Three modes
External Trigger Source:	BNC or Frame Grabber. (Optical isolator on BNC)
Exposure Control:	Manual or Automatic
White-Balance:	Manual or Semi-Automatic
Noise Reduction:	Correlated Double Sampling
Usability Features:	Digital Crosshairs, Color-Plane Multiplexing
Operating Temperature:	0-50 C
Operating Voltage:	12 VDC
Power Consumption:	10 Watts
Weight:	.98 kg
Programmable Functions:	Gain, integration time, multiplexing, trigger modes, custom processing.
Options:	
DirectView Video Output:	NTSC,PAL, S-video and Progressive Scan RGB (1280x1024 max display resolution). Gamma correction. 2x and 4x digital zoom.

APPLICATIONS

The fine resolution and crisp colors of the DT4000 make it the ideal imaging tool for a number of applications. AccuColor real-time color interpolation delivers crisp 24 or 30 bit RGB images directly from the camera. Automatic features for exposure control and white balance provide ease of use. DirectView analog option adds video preview. CameraLink interface supports the latest in acquisition. technology.

- General Purpose Imaging
- Graphics Imaging for Press and Web Graphics
- Medical/Scientific Imaging
- Industrial Vision Applications for Semiconductor Inspection, Color Inspection
- Microscopy
- Metrology

DIMENSIONS



Dimensions in Millimeters

DuncanTech
A SPECTRUM OF SOLUTIONS

11824 Kemper Rd.
Auburn, CA 95603 USA
Phone: (530)-888-6565 Fax: (530)-888-6579
Email: info@duncantech.com
Web: www.duncantech.com

APPENDIX H : OPUS SOLUTIONS

NEA1-JD108

```
 1009   WARNING!  No antenna type was selected.  No antenna offsets or
 1009   pattern will be applied.  Coordinates with reduced accuracy
 1009   will be returned for the antenna phase center.
 1009
 1008   NOTE:  Antenna offsets supplied by the user were zero.  Coordinates
 1008   returned will be for the antenna reference point (ARP).
 1008
                              NGS OPUS SOLUTION REPORT
                              ========================

      USER: mrpepe@earthlink.net                    DATE: April 20, 2005
 RINEX FILE: nea1108u.05o                            TIME: 19:41:24 UTC


  SOFTWARE: page5  0411.19 master2.pl              START: 2005/04/18  20:56:00
 EPHEMERIS: igr13191.eph [rapid]                    STOP: 2005/04/19  02:02:00
  NAV FILE: brdc1080.05n                        OBS USED: 10541 / 11031   :  96%
  ANT NAME: NONE                             # FIXED AMB:    49 /    54   :  91%
ARP HEIGHT: 0.0                              OVERALL RMS: 0.016(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)           ITRF00 (EPOCH:2005.2958)

         X:     -2411948.284(m)   0.008(m)          -2411948.994(m)   0.008(m)
         Y:     -3493581.051(m)   0.038(m)          -3493579.891(m)   0.038(m)
         Z:      4744067.713(m)   0.026(m)           4744067.836(m)   0.026(m)

       LAT:   48 22  0.84107      0.010(m)        48 22  0.85705      0.010(m)
     E LON:  235 22 44.48654      0.015(m)       235 22 44.42613      0.015(m)
     W LON:  124 37 15.51346      0.015(m)       124 37 15.57387      0.015(m)
    EL HGT:          -13.280(m)   0.043(m)                -13.554(m)   0.043(m)
 ORTHO HGT:            7.568(m)   0.050(m) [Geoid03 NAVD88]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 10)         SPC (4601 WA N)
Northing (Y) [meters]     5358350.449           158881.416
Easting (X)  [meters]      379944.205           219482.676
Convergence  [degrees]    -1.21168475          -2.81997693
Point Scale                0.99977709           0.99995168
Combined Factor            0.99977917           0.99995376

US NATIONAL GRID DESIGNATOR: 10UCU7994458350(NAD 83)



                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
AF9668 PABH PACIFIC BEACH CORS ARP         N471246.061 W1241216.437  132056.4
AF9502 WHD1 WHIDBEY ISLAND 1 CORS ARP      N481845.760 W1224146.055  142817.2
AF9670 SEDR SEDRO WOOLEY DNR CORS ARP      N483117.591 W1221325.791  178165.5

                 NEAREST NGS PUBLISHED CONTROL POINT
TS0340      944 3090 A TIDAL               N482200.745 W1243715.669       4.4

This position was computed without any knowledge by the National Geodetic
Survey regarding the equipment or field operating procedures used.
```

T340-JD108

```
 1009   WARNING!  No antenna type was selected.  No antenna offsets or
 1009   pattern will be applied.  Coordinates with reduced accuracy
 1009   will be returned for the antenna phase center.
 1009
 1008   NOTE:  Antenna offsets supplied by the user were zero. Coordinates
 1008   returned will be for the antenna reference point (ARP).
 1008
                              NGS OPUS SOLUTION REPORT
                              ========================

      USER: josevim@hotmail.com                    DATE: April 30, 2005
RINEX FILE: t340108n.05o                           TIME: 23:04:09 UTC


  SOFTWARE: page5  0411.19 master23.pl            START: 2005/04/18 13:47:00
 EPHEMERIS: igr13191.eph [rapid]                   STOP: 2005/04/18 20:23:00
  NAV FILE: brdc1080.05n                       OBS USED: 11066 / 11535  :  96%
  ANT NAME: NONE                             # FIXED AMB:    74 /    74  : 100%
ARP HEIGHT: 0.0                              OVERALL RMS: 0.019(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)            ITRF00
(EPOCH:2005.2951)

         X:     -2411952.183(m)   0.016(m)          -2411952.893(m)  0.016(m)
         Y:     -3493581.182(m)   0.023(m)          -3493580.022(m)  0.023(m)
         Z:      4744065.993(m)   0.034(m)           4744066.116(m)  0.034(m)

       LAT:   48 22  0.74787      0.002(m)        48 22  0.76385     0.002(m)
     E LON:  235 22 44.33426      0.003(m)       235 22 44.27385     0.003(m)
     W LON:  124 37 15.66574      0.003(m)       124 37 15.72615     0.003(m)
    EL HGT:          -13.022(m)   0.043(m)               -13.297(m)  0.043(m)
 ORTHO HGT:            7.826(m)   0.050(m) [Geoid03 NAVD88]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 10)        SPC (4601 WA N)
Northing (Y) [meters]     5358347.638          158878.695
Easting (X)  [meters]      379941.012          219479.404
Convergence  [degrees]    -1.21171589         -2.82000842
Point Scale                0.99977710          0.99995168
Combined Factor            0.99977914          0.99995372

US NATIONAL GRID DESIGNATOR: 10UCU7994158348(NAD 83)



                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
AF9502 WHD1 WHIDBEY ISLAND 1 CORS ARP      N481845.760 W1224146.055 142820.2
AH7396 SEAW SEATTLE WEATHER CORS ARP       N474113.201 W1221522.627 191876.5
AF9670 SEDR SEDRO WOOLEY DNR CORS ARP      N483117.591 W1221325.791 178168.9

                 NEAREST NGS PUBLISHED CONTROL POINT
TS0340      944 3090 A TIDAL               N482200.745 W1243715.669      0.0

This position was computed without any knowledge by the National Geodetic
Survey regarding the equipment or field operating procedures used.

 8002   The Opus solution for your submitted RINEX file appears to be
 8002   quite close to an NGS published control point. This suggests that
 8002   you may have set your GPS receiver up over an NGS control point.
 8002   Furthermore, our files indicate that this control point has not
 8002   been recovered in the last five years.
 8002   If you did indeed recover an NGS control point, we would
 8002   appreciate receiving this information through our web based
 8002   Mark Recovery Form at
 8002   http://www.ngs.noaa.gov/products_services.shtml#MarkRecoveryForm.
 8002
```

T340-JD108

```
 1009   WARNING!  No antenna type was selected.  No antenna offsets or
 1009   pattern will be applied.  Coordinates with reduced accuracy
 1009   will be returned for the antenna phase center.
 1009
 1008   NOTE:  Antenna offsets supplied by the user were zero.  Coordinates
 1008   returned will be for the antenna reference point (ARP).
 1008
                              NGS OPUS SOLUTION REPORT
                              ========================

     USER: mrpepe@earthlink.net                    DATE: April 23, 2005
RINEX FILE: bt34108v.05o                           TIME: 02:36:44 UTC


  SOFTWARE: page5  0411.19 master23.pl            START: 2005/04/18  21:02:00
 EPHEMERIS: igr13191.eph [rapid]                   STOP: 2005/04/19  02:01:00
  NAV FILE: brdc1080.05n                       OBS USED:  9360 / 10564   :  89%
  ANT NAME: NONE                             # FIXED AMB:    55 /    60   :  92%
ARP HEIGHT: 0.0                              OVERALL RMS: 0.024(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)            ITRF00 (EPOCH:2005.2958)

         X:     -2411952.189(m)   0.009(m)          -2411952.899(m)   0.009(m)
         Y:     -3493581.167(m)   0.079(m)          -3493580.007(m)   0.079(m)
         Z:      4744065.994(m)   0.058(m)           4744066.117(m)   0.058(m)

       LAT:   48 22  0.74810      0.019(m)        48 22  0.76409      0.019(m)
     E LON:  235 22 44.33360      0.038(m)       235 22 44.27320      0.038(m)
     W LON:  124 37 15.66640      0.038(m)       124 37 15.72680      0.038(m)
    EL HGT:          -13.028(m)   0.088(m)               -13.302(m)   0.088(m)
 ORTHO HGT:            7.820(m)   0.092(m) [Geoid03 NAVD88]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 10)         SPC (4601 WA N)
Northing (Y) [meters]     5358347.645           158878.703
Easting (X)  [meters]      379940.998           219479.391
Convergence  [degrees]    -1.21171603          -2.82000855
Point Scale                0.99977710           0.99995168
Combined Factor            0.99977914           0.99995372

US NATIONAL GRID DESIGNATOR: 10UCU7994158348(NAD 83)



                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
AF9502 WHD1 WHIDBEY ISLAND 1 CORS ARP      N481845.760 W1224146.055   142820.2
AH7396 SEAW SEATTLE WEATHER CORS ARP       N474113.201 W1221522.627   191876.5
AF9670 SEDR SEDRO WOOLEY DNR CORS ARP      N483117.591 W1221325.791   178168.9

                 NEAREST NGS PUBLISHED CONTROL POINT
TS0340      944 3090 A TIDAL               N482200.745 W1243715.669       0.0

This position was computed without any knowledge by the National Geodetic
Survey regarding the equipment or field operating procedures used.

 8002   The Opus solution for your submitted RINEX file appears to be
 8002   quite close to an NGS published control point. This suggests that
 8002   you may have set your GPS receiver up over an NGS control point.
 8002   Furthermore, our files indicate that this control point has not
 8002   been recovered in the last five years.
 8002   If you did indeed recover an NGS control point, we would
 8002   appreciate receiving this information through our web based
 8002   Mark Recovery Form at
 8002   http://www.ngs.noaa.gov/products_services.shtml#MarkRecoveryForm.
 8002
```

NEA1-JD109

```
1009   WARNING!  No antenna type was selected.  No antenna offsets or
1009   pattern will be applied.  Coordinates with reduced accuracy
1009   will be returned for the antenna phase center.
1009
1008   NOTE:  Antenna offsets supplied by the user were zero. Coordinates
1008   returned will be for the antenna reference point (ARP).
1008
                             NGS OPUS SOLUTION REPORT
                             ========================

     USER: josevim@hotmail.com                     DATE: May 01, 2005
RINEX FILE: nea1109o.05o                            TIME: 00:23:32 UTC


  SOFTWARE: page5  0411.19 master18.pl            START: 2005/04/19 14:09:00
 EPHEMERIS: igr13192.eph [rapid]                   STOP: 2005/04/20 01:02:00
  NAV FILE: brdc1090.05n                       OBS USED: 22348 / 22867  :  98%
  ANT NAME: NONE                            # FIXED AMB:    81 /    81  : 100%
ARP HEIGHT: 0.0                             OVERALL RMS: 0.016(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)           ITRF00 (EPOCH:2005.2981)

         X:     -2411946.124(m)   0.016(m)          -2411946.834(m)  0.016(m)
         Y:     -3493579.455(m)   0.015(m)          -3493578.295(m)  0.015(m)
         Z:      4744069.451(m)   0.026(m)           4744069.574(m)  0.026(m)

       LAT:   48 22  0.93993      0.007(m)       48 22  0.95591      0.007(m)
     E LON:  235 22 44.52884      0.009(m)      235 22 44.46844      0.009(m)
     W LON:  124 37 15.47116      0.009(m)      124 37 15.53156      0.009(m)
    EL HGT:          -13.669(m)   0.033(m)               -13.943(m)  0.033(m)
 ORTHO HGT:            7.178(m)   0.042(m) [Geoid03 NAVD88]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 10)         SPC (4601 WA N)
Northing (Y) [meters]     5358353.483           158884.423
Easting (X)  [meters]      379945.140           219483.696
Convergence  [degrees]    -1.21167648          -2.81996818
Point Scale                0.99977709           0.99995168
Combined Factor            0.99977923           0.99995383

US NATIONAL GRID DESIGNATOR: 10UCU7994558353(NAD 83)



                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE
DISTANCE(m)
AF9668 PABH PACIFIC BEACH CORS ARP        N471246.061 W1241216.437 132059.1
AF9502 WHD1 WHIDBEY ISLAND 1 CORS ARP     N481845.760 W1224146.055 142816.4
AF9670 SEDR SEDRO WOOLEY DNR CORS ARP     N483117.591 W1221325.791 178164.3

                 NEAREST NGS PUBLISHED CONTROL POINT
TS0340      944 3090 A TIDAL              N482200.745 W1243715.669      7.3

This position was computed without any knowledge by the National Geodetic
Survey regarding the equipment or field operating procedures used.
```

T340-JD109

```
 1009   WARNING!  No antenna type was selected.  No antenna offsets or
 1009   pattern will be applied.  Coordinates with reduced accuracy
 1009   will be returned for the antenna phase center.
 1009
 1008   NOTE:  Antenna offsets supplied by the user were zero. Coordinates
 1008   returned will be for the antenna reference point (ARP).
 1008
                              NGS OPUS SOLUTION REPORT
                              ========================

     USER: josevim@hotmail.com                    DATE: April 30, 2005
RINEX FILE: t340109n.05o                          TIME: 23:45:20 UTC


  SOFTWARE: page5  0411.19 master25.pl           START: 2005/04/19 13:53:00
 EPHEMERIS: igr13192.eph [rapid]                  STOP: 2005/04/20 00:33:30
  NAV FILE: brdc1090.05n                      OBS USED: 21783 / 22834  : 95%
  ANT NAME: NONE                           # FIXED AMB:    97 /    98  : 99%
ARP HEIGHT: 0.0                            OVERALL RMS: 0.021(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)            ITRF00(EPOCH:2005.2981)

         X:     -2411952.165(m)   0.016(m)          -2411952.875(m)  0.016(m)
         Y:     -3493581.147(m)   0.019(m)          -3493579.987(m)  0.019(m)
         Z:      4744065.946(m)   0.030(m)           4744066.069(m)  0.030(m)

       LAT:   48 22  0.74780      0.005(m)       48 22  0.76378      0.005(m)
     E LON:  235 22 44.33401      0.009(m)      235 22 44.27360      0.009(m)
     W LON:  124 37 15.66599      0.009(m)      124 37 15.72640      0.009(m)
    EL HGT:          -13.084(m)   0.039(m)               -13.358(m)  0.039(m)
 ORTHO HGT:            7.764(m)   0.046(m) [Geoid03 NAVD88]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 10)         SPC (4601 WA N)
Northing (Y) [meters]     5358347.636           158878.693
Easting (X)  [meters]      379941.007           219479.399
Convergence  [degrees]    -1.21171595          -2.82000847
Point Scale                0.99977710           0.99995168
Combined Factor            0.99977915           0.99995373

US NATIONAL GRID DESIGNATOR: 10UCU7994158348(NAD 83)



                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE
DISTANCE(m)
AF9668 PABH PACIFIC BEACH CORS ARP        N471246.061 W1241216.437 132054.3
AF9502 WHD1 WHIDBEY ISLAND 1 CORS ARP     N481845.760 W1224146.055 142820.2
AF9670 SEDR SEDRO WOOLEY DNR CORS ARP     N483117.591 W1221325.791 178168.9

                 NEAREST NGS PUBLISHED CONTROL POINT
TS0340      944 3090 A TIDAL              N482200.745 W1243715.669      0.0

This position was computed without any knowledge by the National Geodetic
Survey regarding the equipment or field operating procedures used.

 8002   The Opus solution for your submitted RINEX file appears to be
 8002   quite close to an NGS published control point. This suggests that
 8002   you may have set your GPS receiver up over an NGS control point.
 8002   Furthermore, our files indicate that this control point has not
 8002   been recovered in the last five years.
 8002   If you did indeed recover an NGS control point, we would
 8002   appreciate receiving this information through our web based
 8002   Mark Recovery Form at
 8002  http://www.ngs.noaa.gov/products_services.shtml#MarkRecoveryForm.
 8002
```

NEA1-JD110

```
 1009   WARNING!  No antenna type was selected.  No antenna offsets or
 1009   pattern will be applied.  Coordinates with reduced accuracy
 1009   will be returned for the antenna phase center.
 1009
 1008   NOTE:  Antenna offsets supplied by the user were zero. Coordinates
 1008   returned will be for the antenna reference point (ARP).
 1008
                              NGS OPUS SOLUTION REPORT
                              ========================

      USER: josevim@hotmail.com                    DATE: May 01, 2005
RINEX FILE: nea1110p.05o                           TIME: 01:12:11 UTC


  SOFTWARE: page5  0411.19 master2.pl             START: 2005/04/20 15:14:00
 EPHEMERIS: igr13193.eph [rapid]                   STOP: 2005/04/21 00:01:00
  NAV FILE: brdc1100.05n                       OBS USED: 18991 / 19522  :  97%
  ANT NAME: NONE                            # FIXED AMB:    77 /    78  :  99%
ARP HEIGHT: 0.0                             OVERALL RMS: 0.019(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)            ITRF00(EPOCH:2005.3009)

         X:     -2411946.178(m)   0.010(m)          -2411946.888(m)  0.010(m)
         Y:     -3493579.537(m)   0.013(m)          -3493578.377(m)  0.013(m)
         Z:      4744069.555(m)   0.018(m)           4744069.678(m)  0.018(m)

       LAT:   48 22  0.93979      0.013(m)        48 22  0.95577     0.013(m)
     E LON:  235 22 44.52895      0.009(m)       235 22 44.46854     0.009(m)
     W LON:  124 37 15.47105      0.009(m)       124 37 15.53146     0.009(m)
    EL HGT:          -13.526(m)   0.018(m)               -13.800(m)  0.018(m)
 ORTHO HGT:            7.321(m)   0.031(m) [Geoid03 NAVD88]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 10)         SPC (4601 WA N)
Northing (Y) [meters]     5358353.479           158884.419
Easting (X)  [meters]      379945.142           219483.698
Convergence  [degrees]    -1.21167646          -2.81996816
Point Scale                0.99977709           0.99995168
Combined Factor            0.99977921           0.99995380

US NATIONAL GRID DESIGNATOR: 10UCU7994558353(NAD 83)



                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE
DISTANCE(m)
AF9668 PABH PACIFIC BEACH CORS ARP        N471246.061 W1241216.437 132059.1
AF9502 WHD1 WHIDBEY ISLAND 1 CORS ARP     N481845.760 W1224146.055 142816.4
AF9670 SEDR SEDRO WOOLEY DNR CORS ARP     N483117.591 W1221325.791 178164.3

                 NEAREST NGS PUBLISHED CONTROL POINT
TS0340      944 3090 A TIDAL              N482200.745 W1243715.669      7.3

This position was computed without any knowledge by the National
Geodetic
Survey regarding the equipment or field operating procedures used.
```

T340-JD110

```
 1009   WARNING!  No antenna type was selected.  No antenna offsets or
 1009   pattern will be applied.  Coordinates with reduced accuracy
 1009   will be returned for the antenna phase center.
 1009
 1008   NOTE:  Antenna offsets supplied by the user were zero.  Coordinates
 1008   returned will be for the antenna reference point (ARP).
 1008
                              NGS OPUS SOLUTION REPORT
                              ========================

      USER: mrpepe@earthlink.net                    DATE: April 23, 2005
RINEX FILE: t340110p.05o                            TIME: 16:27:56 UTC


  SOFTWARE: page5  0411.19 master30.pl             START: 2005/04/20  15:03:00
 EPHEMERIS: igr13193.eph [rapid]                    STOP: 2005/04/21  00:00:00
  NAV FILE: brdc1100.05n                        OBS USED: 18892 / 19871   :  95%
  ANT NAME: NONE                             # FIXED AMB:   103 /   106   :  97%
ARP HEIGHT: 0.0                              OVERALL RMS: 0.024(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)           ITRF00 (EPOCH:2005.3009)

         X:     -2411952.199(m)   0.012(m)          -2411952.909(m)   0.012(m)
         Y:     -3493581.196(m)   0.022(m)          -3493580.036(m)   0.022(m)
         Z:      4744066.017(m)   0.024(m)           4744066.140(m)   0.024(m)

       LAT:   48 22  0.74788      0.013(m)       48 22  0.76387      0.013(m)
     E LON:  235 22 44.33400      0.012(m)      235 22 44.27360      0.012(m)
     W LON:  124 37 15.66600      0.012(m)      124 37 15.72640      0.012(m)
    EL HGT:          -12.991(m)   0.029(m)               -13.265(m)   0.029(m)
 ORTHO HGT:            7.857(m)   0.039(m) [Geoid03 NAVD88]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 10)         SPC (4601 WA N)
Northing (Y) [meters]     5358347.638           158878.696
Easting (X)  [meters]      379941.007           219479.399
Convergence  [degrees]    -1.21171595          -2.82000847
Point Scale                0.99977710           0.99995168
Combined Factor            0.99977914           0.99995372

US NATIONAL GRID DESIGNATOR: 10UCU7994158348(NAD 83)



                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
AF9668 PABH PACIFIC BEACH CORS ARP         N471246.061 W1241216.437  132054.4
AF9502 WHD1 WHIDBEY ISLAND 1 CORS ARP      N481845.760 W1224146.055  142820.2
AF9670 SEDR SEDRO WOOLEY DNR CORS ARP      N483117.591 W1221325.791  178168.9

                 NEAREST NGS PUBLISHED CONTROL POINT
TS0340      944 3090 A TIDAL               N482200.745 W1243715.669       0.0

This position was computed without any knowledge by the National Geodetic
Survey regarding the equipment or field operating procedures used.

 8002   The Opus solution for your submitted RINEX file appears to be
 8002   quite close to an NGS published control point. This suggests that
 8002   you may have set your GPS receiver up over an NGS control point.
 8002   Furthermore, our files indicate that this control point has not
 8002   been recovered in the last five years.
 8002   If you did indeed recover an NGS control point, we would
 8002   appreciate receiving this information through our web based
 8002   Mark Recovery Form at
 8002   http://www.ngs.noaa.gov/products_services.shtml#MarkRecoveryForm.
 8002
```

T340-JD112

```
 1009   WARNING!  No antenna type was selected.  No antenna offsets or
 1009   pattern will be applied.  Coordinates with reduced accuracy
 1009   will be returned for the antenna phase center.
 1009
 1008   NOTE:  Antenna offsets supplied by the user were zero. Coordinates
 1008   returned will be for the antenna reference point (ARP).
 1008
                              NGS OPUS SOLUTION REPORT
                              ========================

     USER: josevim@hotmail.com                    DATE: April 30, 2005
RINEX FILE: t340112p.05o                          TIME: 23:31:13 UTC


  SOFTWARE: page5  0411.19 master10.pl           START: 2005/04/22 15:36:00
 EPHEMERIS: igr13195.eph [rapid]                  STOP: 2005/04/23 01:56:00
  NAV FILE: brdc1120.05n                      OBS USED: 21481 / 22355  :  96%
  ANT NAME: NONE                           # FIXED AMB:   115 /   116  :  99%
ARP HEIGHT: 0.0                            OVERALL RMS: 0.024(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)           ITRF00(EPOCH:2005.3065)

         X:     -2411952.197(m)   0.009(m)          -2411952.907(m)  0.009(m)
         Y:     -3493581.191(m)   0.001(m)          -3493580.031(m)  0.001(m)
         Z:      4744066.007(m)   0.027(m)           4744066.130(m)  0.027(m)

       LAT:   48 22  0.74779      0.014(m)       48 22  0.76378     0.014(m)
     E LON:  235 22 44.33395      0.007(m)      235 22 44.27354     0.007(m)
     W LON:  124 37 15.66605      0.007(m)      124 37 15.72646     0.007(m)
    EL HGT:          -13.002(m)   0.023(m)               -13.276(m)  0.023(m)
 ORTHO HGT:            7.846(m)   0.034(m) [Geoid03 NAVD88]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 10)        SPC (4601 WA N)
Northing (Y) [meters]     5358347.636          158878.693
Easting (X)  [meters]      379941.005          219479.398
Convergence  [degrees]    -1.21171596         -2.82000848
Point Scale                0.99977710          0.99995168
Combined Factor            0.99977914          0.99995372

US NATIONAL GRID DESIGNATOR: 10UCU7994158348(NAD 83)



                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
AF9668 PABH PACIFIC BEACH CORS ARP         N471246.061 W1241216.437 132054.4
AF9502 WHD1 WHIDBEY ISLAND 1 CORS ARP      N481845.760 W1224146.055 142820.2
AF9670 SEDR SEDRO WOOLEY DNR CORS ARP      N483117.591 W1221325.791 178168.9

                 NEAREST NGS PUBLISHED CONTROL POINT
TS0340      944 3090 A TIDAL               N482200.745 W1243715.669      0.0

This position was computed without any knowledge by the National Geodetic
Survey regarding the equipment or field operating procedures used.

 8002   The Opus solution for your submitted RINEX file appears to be
 8002   quite close to an NGS published control point. This suggests that
 8002   you may have set your GPS receiver up over an NGS control point.
 8002   Furthermore, our files indicate that this control point has not
 8002   been recovered in the last five years.
 8002   If you did indeed recover an NGS control point, we would
 8002   appreciate receiving this information through our web based
 8002   Mark Recovery Form at
 8002  http://www.ngs.noaa.gov/products_services.shtml#MarkRecoveryForm.
 8002
```

T340-JD113

```
 1009   WARNING!  No antenna type was selected.  No antenna offsets or
 1009   pattern will be applied.  Coordinates with reduced accuracy
 1009   will be returned for the antenna phase center.
 1009
 1008   NOTE:  Antenna offsets supplied by the user were zero. Coordinates
 1008   returned will be for the antenna reference point (ARP).
 1008
                              NGS OPUS SOLUTION REPORT
                              ========================

     USER: josevim@hotmail.com                    DATE: May 01, 2005
RINEX FILE: t340113p.05o                          TIME: 00:36:49 UTC


  SOFTWARE: page5  0411.19 master11.pl           START: 2005/04/23 15:02:00
 EPHEMERIS: igr13196.eph [rapid]                  STOP: 2005/04/23 22:18:00
  NAV FILE: brdc1130.05n                      OBS USED: 15637 / 16223  :  96%
  ANT NAME: NONE                             # FIXED AMB:    88 /    90  :  98%
ARP HEIGHT: 0.0                             OVERALL RMS: 0.020(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)           ITRF00 (EPOCH:2005.3090)

         X:     -2411952.191(m)   0.020(m)          -2411952.901(m)  0.020(m)
         Y:     -3493581.175(m)   0.023(m)          -3493580.015(m)  0.023(m)
         Z:      4744065.994(m)   0.039(m)           4744066.117(m)  0.039(m)

       LAT:   48 22  0.74792      0.004(m)       48 22  0.76390     0.004(m)
     E LON:  235 22 44.33374      0.006(m)      235 22 44.27334     0.006(m)
     W LON:  124 37 15.66626      0.006(m)      124 37 15.72666     0.006(m)
    EL HGT:          -13.023(m)   0.049(m)               -13.297(m)  0.049(m)
 ORTHO HGT:            7.825(m)   0.055(m) [Geoid03 NAVD88]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 10)         SPC (4601 WA N)
Northing (Y) [meters]     5358347.640           158878.697
Easting (X)  [meters]      379941.001           219479.394
Convergence  [degrees]    -1.21171600          -2.82000853
Point Scale                0.99977710           0.99995168
Combined Factor            0.99977914           0.99995372

US NATIONAL GRID DESIGNATOR: 10UCU7994158348(NAD 83)



                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
AF9668 PABH PACIFIC BEACH CORS ARP         N471246.061 W1241216.437 132054.4
AF9502 WHD1 WHIDBEY ISLAND 1 CORS ARP      N481845.760 W1224146.055 142820.2
AF9670 SEDR SEDRO WOOLEY DNR CORS ARP      N483117.591 W1221325.791 178168.9

                 NEAREST NGS PUBLISHED CONTROL POINT
TS0340      944 3090 A TIDAL               N482200.745 W1243715.669      0.0

This position was computed without any knowledge by the National Geodetic
Survey regarding the equipment or field operating procedures used.

 8002   The Opus solution for your submitted RINEX file appears to be
 8002   quite close to an NGS published control point. This suggests that
 8002   you may have set your GPS receiver up over an NGS control point.
 8002   Furthermore, our files indicate that this control point has not
 8002   been recovered in the last five years.
 8002   If you did indeed recover an NGS control point, we would
 8002   appreciate receiving this information through our web based
 8002   Mark Recovery Form at
 8002  http://www.ngs.noaa.gov/products_services.shtml#MarkRecoveryForm.
 8002
```

NEA1-JD114

```
 1009   WARNING!  No antenna type was selected.  No antenna offsets or
 1009   pattern will be applied.  Coordinates with reduced accuracy
 1009   will be returned for the antenna phase center.
 1009
 1008   NOTE:  Antenna offsets supplied by the user were zero. Coordinates
 1008   returned will be for the antenna reference point (ARP).
 1008
                              NGS OPUS SOLUTION REPORT
                              ========================

      USER: josevim@hotmail.com                    DATE: May 01, 2005
RINEX FILE: nea1114r.05o                           TIME: 01:42:57 UTC


  SOFTWARE: page5  0411.19 master19.pl            START: 2005/04/24 17:30:00
 EPHEMERIS: igr13200.eph [rapid]                   STOP: 2005/04/24 17:57:00
  NAV FILE: brdc1140.05n                       OBS USED:    60 /    87  :  69%
  ANT NAME: NONE                              # FIXED AMB:     3 /     3  : 100%
ARP HEIGHT: 0.0                             OVERALL RMS: 0.007(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)            ITRF00 (EPOCH:2005.3116)

         X:     -2411947.609(m)   1.962(m)          -2411948.319(m)  1.962(m)
         Y:     -3493584.830(m)   0.452(m)          -3493583.670(m)  0.452(m)
         Z:      4744084.161(m)   0.000(m)           4744084.284(m)  0.000(m)

       LAT:   48 22  1.12887      1.112(m)        48 22  1.14486     1.112(m)
     E LON:  235 22 44.61784      1.355(m)       235 22 44.55743     1.355(m)
     W LON:  124 37 15.38216      1.355(m)       124 37 15.44257     1.355(m)
    EL HGT:            0.825(m)   0.988(m)                 0.550(m)  0.988(m)
 ORTHO HGT:           21.672(m)   0.988(m) [Geoid03 NAVD88]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 10)         SPC (4601 WA N)
Northing (Y) [meters]     5358359.278           158890.162
Easting (X)  [meters]      379947.095           219485.813
Convergence  [degrees]    -1.21165899          -2.81994977
Point Scale                0.99977708           0.99995169
Combined Factor            0.99977695           0.99995156

US NATIONAL GRID DESIGNATOR: 10UCU7994758359(NAD 83)



                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
AF9668 PABH PACIFIC BEACH CORS ARP      N471246.061 W1241216.437 132064.9
AF9502 WHD1 WHIDBEY ISLAND 1 CORS ARP   N481845.760 W1224146.055 142815.7
AF9670 SEDR SEDRO WOOLEY DNR CORS ARP   N483117.591 W1221325.791 178161.8

                 NEAREST NGS PUBLISHED CONTROL POINT
TS0340      944 3090 A TIDAL            N482200.745 W1243715.669     13.3

This position was computed without any knowledge by the National Geodetic
Survey regarding the equipment or field operating procedures used.
```

T340-JD114

```
 1009   WARNING!  No antenna type was selected.  No antenna offsets or
 1009   pattern will be applied.  Coordinates with reduced accuracy
 1009   will be returned for the antenna phase center.
 1009
 1008   NOTE:  Antenna offsets supplied by the user were zero. Coordinates
 1008   returned will be for the antenna reference point (ARP).
 1008
                              NGS OPUS SOLUTION REPORT
                              ========================

      USER: josevim@hotmail.com                    DATE: May 01, 2005
RINEX FILE: t340114r.05o                           TIME: 00:52:03 UTC


  SOFTWARE: page5  0411.19 master18.pl            START: 2005/04/24 17:17:00
 EPHEMERIS: igr13200.eph [rapid]                   STOP: 2005/04/24 22:53:00
  NAV FILE: brdc1140.05n                       OBS USED: 13562 / 14044  :  97%
  ANT NAME: NONE                            # FIXED AMB:    65 /    65  : 100%
ARP HEIGHT: 0.0                             OVERALL RMS: 0.020(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)           ITRF00 (EPOCH:2005.3119)

         X:     -2411952.179(m)   0.016(m)          -2411952.889(m)  0.016(m)
         Y:     -3493581.161(m)   0.016(m)          -3493580.001(m)  0.016(m)
         Z:      4744065.968(m)   0.034(m)           4744066.091(m)  0.034(m)

       LAT:   48 22  0.74780      0.009(m)        48 22  0.76378     0.009(m)
     E LON:  235 22 44.33384      0.004(m)       235 22 44.27343     0.004(m)
     W LON:  124 37 15.66616      0.004(m)       124 37 15.72657     0.004(m)
    EL HGT:          -13.054(m)   0.038(m)               -13.328(m)  0.038(m)
 ORTHO HGT:            7.794(m)   0.046(m) [Geoid03 NAVD88]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 10)         SPC (4601 WA N)
Northing (Y) [meters]     5358347.636          158878.694
Easting (X)  [meters]      379941.003          219479.396
Convergence  [degrees]    -1.21171598         -2.82000851
Point Scale                0.99977710          0.99995168
Combined Factor            0.99977915          0.99995373

US NATIONAL GRID DESIGNATOR: 10UCU7994158348(NAD 83)



                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
AF9668 PABH PACIFIC BEACH CORS ARP         N471246.061 W1241216.437 132054.4
AF9502 WHD1 WHIDBEY ISLAND 1 CORS ARP      N481845.760 W1224146.055 142820.2
AF9670 SEDR SEDRO WOOLEY DNR CORS ARP      N483117.591 W1221325.791 178168.9

                 NEAREST NGS PUBLISHED CONTROL POINT
TS0340      944 3090 A TIDAL               N482200.745 W1243715.669      0.0

This position was computed without any knowledge by the National Geodetic
Survey regarding the equipment or field operating procedures used.

 8002   The Opus solution for your submitted RINEX file appears to be
 8002   quite close to an NGS published control point. This suggests that
 8002   you may have set your GPS receiver up over an NGS control point.
 8002   Furthermore, our files indicate that this control point has not
 8002   been recovered in the last five years.
 8002   If you did indeed recover an NGS control point, we would
 8002   appreciate receiving this information through our web based
 8002   Mark Recovery Form at
 8002   http://www.ngs.noaa.gov/products_services.shtml#MarkRecoveryForm.
 8002
```

APPENDIX I : SHOALS CALIBRATION VALUES USED

SHOALS-1000T SYSTEM#2 **March 30, 2005 – rev1**

A90 (N80Y): March 15 to 18, 2005 **Toronto Calibration**

DAVIS → Auto Process → Topo Parameters

	A90 (N80Y)
horiz_misalign_angle:	+ 0.170
vert_misalign_angle:	+ 1.304
pitch_offset:	- 1.147
topo_elevation_bias_300:	- 0.06
topo_elevation_bias_700:	- 0.06

DAVIS → Utilities → LIDAR Parameters (Hardware - system_params_02.txt)

	A90 (N80Y)
bathy_topo_bias_200:	+ 0.12
bathy_topo_bias_300:	+ 0.12
bathy_topo_bias_400:	+ 0.12
deep_bias_left_200:	- 0.507
deep_bias_left_300:	- 0.520
deep_bias_left_400:	- 0.549
deep_bias_right_200:	- 0.498
deep_bias_right_300:	- 0.511
deep_bias_right_400:	- 0.543
apriori_depth_bias_shallow	- 0.19
apriori_depth_bias_deep	- 0.19
rcvr_horiz_misalign_angle:	+ 0.055
rcvr_vert_misalign_angle:	+ 1.304
imu_sensor_pitch_offset:	- 1.232
scan_x_yaw_misalign_angle:	- 0.150

For information only – do NOT change the following values for processing.

sensorref_antenna_lever_arm (x, y, z): + 1.345, - 0.171, - 0.939
imu_antenna_lever_arm (x, y, z): + 1.418, - 0.401, - 1.354

DAVIS → Utilities → Camera Parameters

	A90 (N80Y)
camera_boresight_roll:	- 0.70
camera_boresight_pitch:	+ 10.72
camera_boresight_heading:	0.00

APPENDIX J : KGPS PROCESSING RESULTS

JD108

Processing Summary Information

Program: POSGPS
Version: 4.10
Project: S:\FP6088-012_LIDAR-OCNMS\03_processing\GCS_GPS\2005-04-18-Flt1A-T340\GPS\2005-04-18-Flt1A-T340.gnv

Solution Type: Combined Fwd/Rev

Number of Epochs:

Total in GPB file:	21241
No processed position:	12815
Missing Fwd or Rev:	3
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0244 (m)
C/A Code:	1.60 (m)
L1 Doppler:	0.129 (m/s)

Fwd/Rev Separation RMS Values:

East:	0.019 (m)
North:	0.067 (m)
Height:	0.074 (m)

Fwd/Rev Sep. RMS for 25%-75% weighting (8420 occurances):

East:	0.019 (m)
North:	0.067 (m)
Height:	0.075 (m)

Quality Number Percentages:

Q 1:	98.6 %
Q 2:	1.4 %
Q 3:	0.0 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	100.0 %
0.10 - 0.30 m:	0.0 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

DOP over Tol:	0.0 %

Baseline Distances:

Maximum:	33.078 (km)
Minimum:	1.200 (km)
Average:	14.475 (km)
First Epoch:	10.681 (km)
Last Epoch:	9.963 (km)

JD108

Processing Summary Information

Program: POSGPS
Version: 4.10
Project: S:\FP6088-012_LIDAR-OCNMS\03_processing\GCS_GPS\2005-04-18-Flt2A-T340\GPS\2005-04-18-Flt2A-T340.gnv

Solution Type: Combined Fwd/Rev

Number of Epochs:

Total in GPB file:	7447
No processed position:	3750
Missing Fwd or Rev:	2
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0237 (m)
C/A Code:	1.37 (m)
L1 Doppler:	0.118 (m/s)

Fwd/Rev Separation RMS Values:

East:	0.185 (m)
North:	0.249 (m)
Height:	0.347 (m)

Fwd/Rev Sep. RMS for 25%-75% weighting (2534 occurances):

East:	0.008 (m)
North:	0.006 (m)
Height:	0.011 (m)

Quality Number Percentages:

Q 1:	96.4 %
Q 2:	0.4 %
Q 3:	0.7 %
Q 4:	1.6 %
Q 5:	0.9 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	77.9 %
0.10 - 0.30 m:	21.7 %
0.30 - 1.00 m:	0.3 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

DOP over Tol:	2.7 %

Baseline Distances:

Maximum:	88.774 (km)
Minimum:	0.878 (km)
Average:	29.459 (km)
First Epoch:	88.640 (km)
Last Epoch:	10.534 (km)

JD108

Processing Summary Information

Program: POSGPS
Version: 4.10
Project: S:\FP6088-012_LIDAR-OCNMS\03_processing\GCS_GPS\2005-04-18-Flt2B-T340\GPS\2005-04-18-Flt2B-T340.gnv

Solution Type: Combined Fwd/Rev

Number of Epochs:

Total in GPB file:	24188
No processed position:	13480
Missing Fwd or Rev:	3
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0263 (m)
C/A Code:	1.37 (m)
L1 Doppler:	0.136 (m/s)

Fwd/Rev Separation RMS Values:

East:	0.013 (m)
North:	0.019 (m)
Height:	0.037 (m)

Fwd/Rev Sep. RMS for 25%-75% weighting (10702 occurances):

East:	0.013 (m)
North:	0.019 (m)
Height:	0.037 (m)

Quality Number Percentages:

Q 1:	99.0 %
Q 2:	1.0 %
Q 3:	0.0 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	97.3 %
0.10 - 0.30 m:	2.7 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

DOP over Tol:	0.0 %

Baseline Distances:

Maximum:	34.930 (km)
Minimum:	1.054 (km)
Average:	14.518 (km)
First Epoch:	10.477 (km)
Last Epoch:	9.886 (km)

JD109

Processing Summary Information

Program: POSGPS
Version: 4.10
Project: S:\FP6088-012_LIDAR-OCNMS\03_processing\GCS_GPS\2005-04-19-Flt1A-T340\GPS\2005-04-19-Flt1A-T340.gnv

Solution Type: Combined Fwd/Rev

Number of Epochs:

Total in GPB file:	18708
No processed position:	12674
Missing Fwd or Rev:	3
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0228 (m)
C/A Code:	1.40 (m)
L1 Doppler:	0.114 (m/s)

Fwd/Rev Separation RMS Values:

East:	0.003 (m)
North:	0.009 (m)
Height:	0.016 (m)

Fwd/Rev Sep. RMS for 25%-75% weighting (6028 occurances):

East:	0.003 (m)
North:	0.009 (m)
Height:	0.016 (m)

Quality Number Percentages:

Q 1:	100.0 %
Q 2:	0.0 %
Q 3:	0.0 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	100.0 %
0.10 - 0.30 m:	0.0 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

DOP over Tol:	0.0 %

Baseline Distances:

Maximum:	32.124 (km)
Minimum:	1.252 (km)
Average:	12.336 (km)
First Epoch:	29.107 (km)
Last Epoch:	27.347 (km)

JD112

Processing Summary Information

Program: POSGPS
Version: 4.10
Project: S:\FP6088-012_LIDAR-OCNMS\03_processing\GCS_GPS\2005-04-22-Flt1A-T340\GPS\2005-04-22-Flt1A-T340.gnv

Solution Type: Combined Fwd/Rev

Number of Epochs:

Total in GPB file:	32375
No processed position:	18234
Missing Fwd or Rev:	3
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0266 (m)
C/A Code:	1.40 (m)
L1 Doppler:	0.118 (m/s)

Fwd/Rev Separation RMS Values:

East:	0.011 (m)
North:	0.016 (m)
Height:	0.033 (m)

Fwd/Rev Sep. RMS for 25%-75% weighting (14135 occurances):

East:	0.011 (m)
North:	0.016 (m)
Height:	0.033 (m)

Quality Number Percentages:

Q 1:	97.9 %
Q 2:	2.1 %
Q 3:	0.0 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	99.9 %
0.10 - 0.30 m:	0.1 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

DOP over Tol:	0.0 %

Baseline Distances:

Maximum:	32.286 (km)
Minimum:	0.991 (km)
Average:	11.249 (km)
First Epoch:	20.636 (km)
Last Epoch:	25.140 (km)

JD113

Processing Summary Information

Program: POSGPS
Version: 4.10
Project: S:\FP6088-012_LIDAR-OCNMS\03_processing\GCS_GPS\2005-04-23-Flt1A-T340\GPS\2005-04-23-Flt1A-T340.gnv

Solution Type: Combined Fwd/Rev

Number of Epochs:

Total in GPB file:	13837
No processed position:	8218
Missing Fwd or Rev:	3
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0283 (m)
C/A Code:	1.48 (m)
L1 Doppler:	0.123 (m/s)

Fwd/Rev Separation RMS Values:

East:	0.012 (m)
North:	0.007 (m)
Height:	0.054 (m)

Fwd/Rev Sep. RMS for 25%-75% weighting (5612 occurances):

East:	0.012 (m)
North:	0.007 (m)
Height:	0.054 (m)

Quality Number Percentages:

Q 1:	99.1 %
Q 2:	0.9 %
Q 3:	0.0 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	100.0 %
0.10 - 0.30 m:	0.0 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

DOP over Tol:	0.0 %

Baseline Distances:

Maximum:	20.996 (km)
Minimum:	0.493 (km)
Average:	8.700 (km)
First Epoch:	9.777 (km)
Last Epoch:	11.363 (km)

JD114

Processing Summary Information

Program: POSGPS
Version: 4.10
Project: S:\FP6088-012_LIDAR-OCNMS\03_processing\GCS_GPS\2005-04-24-Flt1A-T340\GPS\2005-04-24-Flt1A-T340.gnv

Solution Type: Combined Fwd/Rev

Number of Epochs:

Total in GPB file:	30035
No processed position:	17229
Missing Fwd or Rev:	3
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0248 (m)
C/A Code:	1.35 (m)
L1 Doppler:	0.112 (m/s)

Fwd/Rev Separation RMS Values:

East:	0.010 (m)
North:	0.016 (m)
Height:	0.029 (m)

Fwd/Rev Sep. RMS for 25%-75% weighting (12797 occurances):

East:	0.010 (m)
North:	0.016 (m)
Height:	0.029 (m)

Quality Number Percentages:

Q 1:	99.8 %
Q 2:	0.2 %
Q 3:	0.0 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	95.1 %
0.10 - 0.30 m:	4.9 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

DOP over Tol:	0.0 %

Baseline Distances:

Maximum:	31.452 (km)
Minimum:	0.567 (km)
Average:	19.355 (km)
First Epoch:	19.117 (km)
Last Epoch:	18.186 (km)

APPENDIX K : PERSONNEL

Fugro Pelagos – Field Personnel	
Party Chief	Dushan Arumugam
Airborne Operator	Dennis Tobin
Airborne Operator	Derek Johnson
GCS Operator	Jose Martinez
Surveyor – Ground Control	Neil Kussat
Fugro Pelagos – Office Personnel	
Project Manager	Mark MacDonald
Project Manager – LIDAR (Project QC)	Carol Lockhart
Senior Data Analyst	Jose Martinez
Data Analyst/Report	Derek Johnson
Data Analyst/Report	Juan Lopez

ONMS CONSERVATION SERIES PUBLICATIONS

To date, the following reports have been published in the Marine Sanctuaries Conservation Series. All publications are available on the Office of National Marine Sanctuaries website (http://www.sanctuaries.noaa.gov/).

Conservation Science in NOAA's National Marine Sanctuaries: Description and Recent Accomplishments (ONMS-06-04)

Normalization and Characterization of Multibeam Backscatter: Koitlah Point to Point of the Arches, Olympic Coast National Marine Sanctuary (ONMS-06-03)

Developing Alternatives for Optimal Representation of Seafloor Habitats and Associated Communities in Stellwagen Bank National Marine Sanctuary (ONMS-06-02)

Benthic Habitat Mapping in the Olympic Coast National Marine Sanctuary (ONMS-06-01)

Channel Islands Deep Water Monitoring Plan Development Workshop Report (ONMS-05-05)

Movement of yellowtail snapper (*Ocyurus chrysurus* Block 1790) and black grouper (*Mycteroperca bonaci* Poey 1860) in the northern Florida Keys National Marine Sanctuary as determined by acoustic telemetry (MSD-05-4)

The Impacts of Coastal Protection Structures in California's Monterey Bay National Marine Sanctuary (MSD-05-3)

An annotated bibliography of diet studies of fish of the southeast United States and Gray's Reef National Marine Sanctuary (MSD-05-2)

Noise Levels and Sources in the Stellwagen Bank National Marine Sanctuary and the St. Lawrence River Estuary (MSD-05-1)

Biogeographic Analysis of the Tortugas Ecological Reserve (MSD-04-1)

A Review of the Ecological Effectiveness of Subtidal Marine Reserves in Central California (MSD-04-2, MSD-04-3)

Pre-Construction Coral Survey of the M/V Wellwood Grounding Site (MSD-03-1)

Olympic Coast National Marine Sanctuary: Proceedings of the 1998 Research Workshop, Seattle, Washington (MSD-01-04)

Workshop on Marine Mammal Research & Monitoring in the National Marine Sanctuaries (MSD-01-03)

A Review of Marine Zones in the Monterey Bay National Marine Sanctuary (MSD-01-2)

Distribution and Sighting Frequency of Reef Fishes in the Florida Keys National Marine Sanctuary (MSD-01-1)

Flower Garden Banks National Marine Sanctuary: A Rapid Assessment of Coral, Fish, and Algae Using the AGRRA Protocol (MSD-00-3)

The Economic Contribution of Whale watching to Regional Economies: Perspectives From Two National Marine Sanctuaries (MSD-00-2)

Olympic Coast National Marine Sanctuary Area to be Avoided Education and Monitoring Program (MSD-00-1)

Multi-species and Multi-interest Management: an Ecosystem Approach to Market Squid (*Loligo opalescens*) Harvest in California (MSD-99-1)